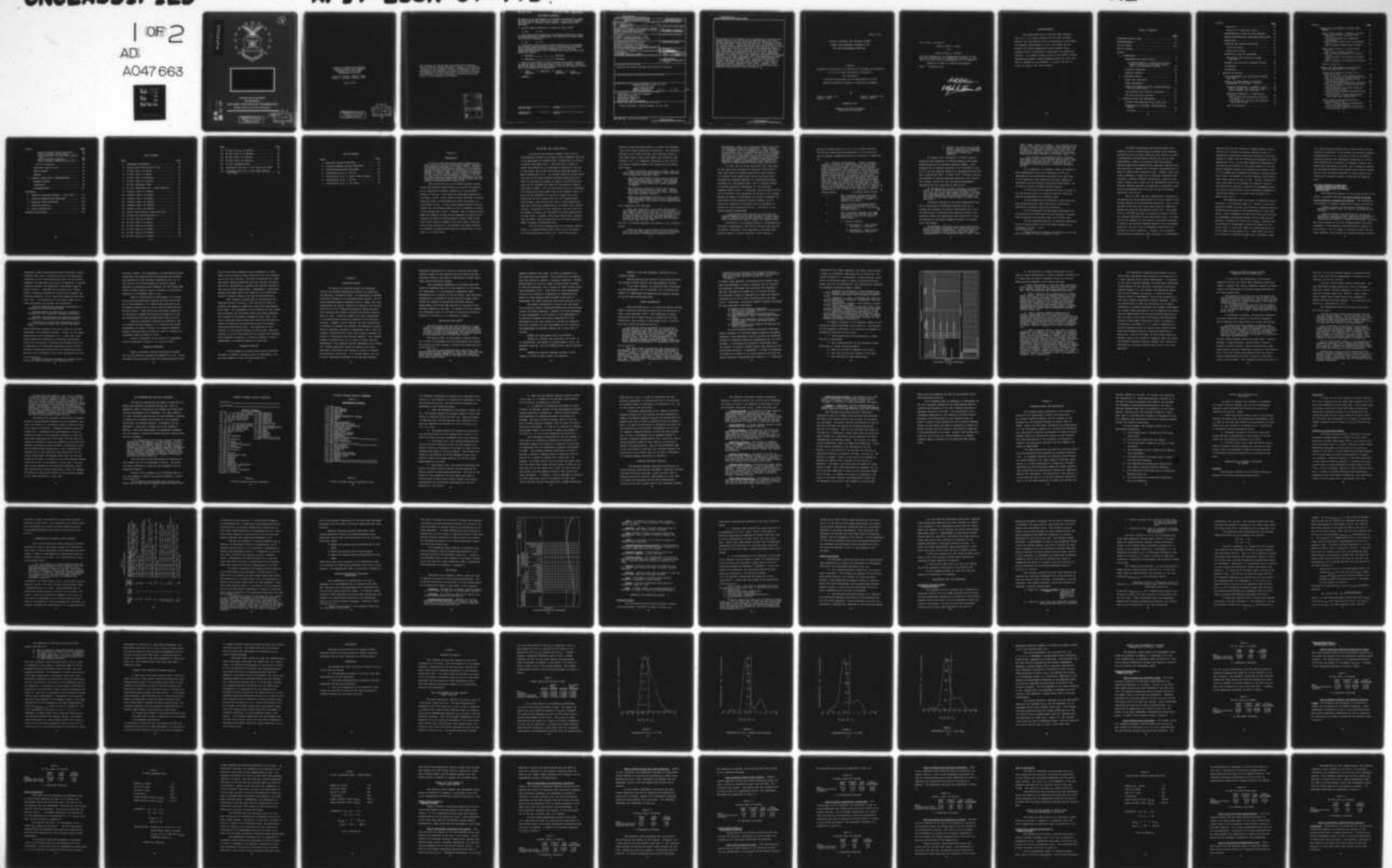
AD-A047 663 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OHIO SCHO--ETC F/G 5/9
A STUDY TO QUANTIFY THE PHYSICAL DEMANDS PLACED UPON PERSONNEL --ETC(U)
SEP 77 F P ARBEIT, H A SCHEAFER

UNCLASSIFIED AFIT-LSSR-37-77B NL

1 OF 2
AD
A047663



3

AF INSTITUTE OF TECHNOLOGY

UNITED STATES AIR FORCE

AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

A STUDY TO QUANTIFY THE PHYSICAL DEMANDS PLACED UPON PERSONNEL ASSIGNED TO AN AIR FORCE MAINTENANCE SPECIALTY

Ferde P. Arbeit, Captain, USAF
Harry A. Scheafer, Captain, USAF

LSSR 37-77B

The contents of the document are technically accurate, and no sensitive items, detrimental ideas, or deliterious information are contained therein. Furthermore, the views expressed in the document are those of the author and do not necessarily reflect the views of the School of Systems and Logistics, the Air University, the United States Air Force, or the Department of Defense.

AFIT RESEARCH ASSESSMENT

The purpose of this questionnaire is to determine the potential for current and future applications of AFIT thesis research. Please return completed questionnaires to: AFIT/SLGR (Thesis Feedback), Wright-Patterson AFB, Ohio 45433.

1. Did this research contribute to a current Air Force project?

   a. Yes b. No

2. Do you believe this research topic is significant enough that it would have been researched (or contracted) by your organization or another agency if AFIT had not researched it?

   a. Yes b. No

3. The benefits of AFIT research can often be expressed by the equivalent value that your agency received by virtue of AFIT performing the research. Can you estimate what this research would have cost if it had been accomplished under contract or if it had been done in-house in terms of manpower and/or dollars?

   a. Man-years ________ $ ________ (Contract).

   b. Man-years ________ $ ________ (In-house).

4. Often it is not possible to attach equivalent dollar values to research, although the results of the research may, in fact, be important. Whether or not you were able to establish an equivalent value for this research (3 above), what is your estimate of its significance?

   a. Highly Significant b. Significant c. Slightly Significant d. Of No Significance

5. Comments:

________________________ ________________________
Name and Grade Position

________________________ ________________________
Organization Location

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER (14) LSSR-37-77B √	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) (6) A STUDY TO QUANTIFY THE PHYSICAL DEMANDS PLACED UPON PERSONNEL ASSIGNED TO AN AIR FORCE MAINTENANCE SPECIALTY.		5. TYPE OF REPORT & PERIOD COVERED (9) Master's Thesis, 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) Ferde P./Arbeit, Captain, USAF Harry A./Scheafer, Captain, USAF		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Graduate Education Division School of Systems and Logistics Air Force Institute of Technology, WPAFB OH		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Department of Research and Administrative Management AFIT/LSGR, WPAFB OH 45433		12. REPORT DATE (11) Sep[redacted]977 13. NUMBER OF PAGES 141 (12) 158 p.
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

APPROVED FOR PUBLIC RELEASE AFR 190-17.

JERRAL F. GUESS, CAPT, USAF
Director of Information

012 250

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Measurement of Physical Demands
Duty/Task Analysis
Observation Worksheet
Statistical Tests
Technical Order Procedures

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Thesis Chairman: Ronald Knipfer, Lt Col, USAF

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

The purpose of this research was to determine if military personnel working in an Air Force maintenance specialty could provide accurate quantitative estimates of the physical severity of their work. This research was done in conjunction with the design study to determine methods for establishing criteria for assigning personnel to Air Force jobs requiring heavy/very heavy work. In this research, an interview and observation instrument was developed from the Air Force Specialty, Specialty Training Standard and Technical Order procedures. Personnel in a sample Air Force Specialty estimated the physical severity of the work associated with three maintenance tasks. Their estimates were compared to a job standard developed through work study methods. The researchers found that, in general, personnel can accurately estimate in quantitative terms the physical demands of their work. However, their estimates were influenced by some job related factors which affected the accuracy of their estimates.

LSSR 37-77B

A STUDY TO QUANTIFY THE PHYSICAL DEMANDS PLACED UPON PERSONNEL ASSIGNED TO AN AIR FORCE MAINTENANCE SPECIALTY

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

Ferde P. Arbeit, BS
Captain, USAF

Harry A. Scheafer, BS
Captain, USAF

September 1977

This thesis, written by

Captain Ferde P. Arbeit

and

Captain Harry A. Scheafer

has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN LOGISTICS MANAGEMENT

DATE: 7 September 1977

COMMITTEE CHAIRMAN

READER

ACKNOWLEDGMENTS

The researchers wish to express their appreciation to Lt. Col. Ronald Knipfer for his work as thesis advisor; Dr. Joe McDaniel for his assistance in developing the research methodology; Lt. Col. John Adams for his helpful and timely suggestions; and to Captain Fred Lawrence for his assistance in developing the statistical analysis. Our special thanks to men of the 4950th Avionics Maintenance Squadron, Radar Navigation Shop for their support in conducting this research. Finally, we wish to thank our typist, Mrs. Carol Stanik.

TABLE OF CONTENTS

Chapter | Page

Chapter | Page

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION

> In the military services physical profiling systems have been limited to medically specified physical requirements associated with career fields. However for selection-classification purposes, no satisfactory method has been available for evaluating the physical demands of military jobs....Valid measures of physical demands in career ladders would be useful information in many areas of human resources management. In the Air Force, physical demand profiles developed from such measures could have impact upon career choices and the selection-classification system [13:5].

The need exists for an Air Force personnel selection-classification system which will permit the matching of an individual's physical capability to the physical demands of the job. This need was recognized because the Air Force, as well as the other military services, has been assigning women to maintenance and other previously all-male career fields. The Air Force Surgeon General has concluded that the average female is only 60 percent as strong as the average male (4:26). However, just as there are many women who possibly should not be assigned to certain maintenance and other Air Force Specialty Codes (AFSC) which place heavy physical demand on the work force, there may also be many men who will not possess the needed strength and stamina to perform efficiently and effectively in such AFSCs (7:1; 13:5; 4:26).

BACKGROUND AND JUSTIFICATION

The end of the military manpower draft and the congressional passage of the Equal Rights Amendment resulted in the Department of Defense (DOD) intensifying its efforts to enlist more women (4:1). This was done in order to offset the possibility of shortages of men due to the end of the draft, and to make the military services models of equal opportunity (4:1). The United States Air Force (USAF) and each of the other military services established programs to increase the number of women in the military services and to increase the number of occupational specialties open to women. The Air Force plan calls for increasing the number of enlisted women from 11,500 members (1972) to about 35,000 personnel by the end of fiscal 1977 (4:1). By the end of 1978, these plans call for approximately 52,000 women, many of whom will work in USAF specialties that were previously predominantly "all-male" skill trades (22:12). In pursuit of this objective, the Air Force has now opened virtually all non-combat Air Force Specialties to women (4:8). However, the United States Code, sections 6015 and 8549, title 10 prohibits the Air Force assigning women to combat environments (4:9).

The Air Force's present goal is to achieve approximately a 15 percent female work force in the non-combat Air Force Specialties (4:16; 7:1). Since women began

entering these non-combat AFSCs, a problem has developed which could reach significant proportions. The potential problem is that there are many jobs involving heavy or very heavy manual labor which women have difficulty performing (7:1). An inspection completed in May, 1976 by the Deputy Inspector General for Inspections and Safety, USAF noted:

> A more significant percentage of women, than men, have trouble doing the more difficult tasks required in the physically demanding AFSCs.
>
> -We tested the relative capabilities of men and women to perform certain tasks in the aircraft and missile maintenance fields. Men completed 99 percent of the tasks while women completed 68 percent.
>
> -The principal reason for women's poor performance was lack of physical strength. However, our tests revelaed that height, size, and reach were also important factors.
>
> -Women also experience difficulty in other physically demanding AFSCs, such as civil engineering, security police, and certain field communications jobs [6:3].

This inspection also revealed:

> Women are doing well in all AFSCs where significant physical strength or stamina is not required. In such AFSCs, women's attrition rate in technical training is similar to men's, their on-the-job performance is rated as highly as men's, they are upgraded as quickly as men, and they are somewhat more satisfied with their jobs than men [6:2].

The lack of physical strength and stamina is not limited to women:

> There has been a small portion of the male force which has been reassigned to less strenuous jobs when they have failed to demonstrate adequate physical

performance. There have always been enough light jobs to accommodate these few individuals. This problem has increased with the introduction of women, because it now appears that a significant portion of the women recruits, if not the majority, are not able to perform heavy and very heavy manual work with the efficiency and reliability required. Because this inability does not apply to women only, and because some women are physically capable of performing on the heavier jobs, women as a group cannot be denied these jobs [7:1].

In 1974, the Air Force recognized that some women and men were being assigned to industrial trade AFSCs in which they could not perform effectively and started to (1) identify those specialties having heavy/very heavy strength and endurance demands, (2) develop performance standards for troublesome AFSCs, and (3) develop methods to evaluate personnel performance in the physically demanding AFSCs (4:18). In addition, the Air Force's Director of Personnel Plans requested the Office of the Surgeon General to assist in developing (1) physical standards for those AFSCs having strenuous physical demand, and (2) methods for measuring the capabilities of personnel to perform in those specialties (4:19). The Office of the Surgeon General recommended:

> ...regulations which provided for measuring the physical capacity of both men and women in four stages, based on factors such as age, strength, stamina, muscular coordination, height, weight, and energy [4:19].

The Office of the Surgeon General's recommendations have been incorporated in AFR 160-43, Medical Examinations and Medical Standards, which represents a physical work capacity profile, called "X-Factor", which assigns a

physical fitness score (1, 2, 3, or 4) to each enlistee. The official definition and description of the "X-Factor" and the present subjective evaluation technique is described as:

> "X". Physical Work Capacity. Overall strength, stamina, and muscular coordination, as they relate to a person's ability to work a prolonged workday/week under varying environments and a variety of occupational requirements, are considered. The Physical Work Capacity factor is also influenced by other characteristics such as agility, biological age, body structure, obesity, height/weight, and personal living habits. The "X" factor may be influenced by other profile factors, but will not necessarily numerically correspond with them. The "X" factor will be judgmentally determined following the physical examination when no means for local objective evaluation, as described in attachment 2, are available. As with other profile factors, factor "X" is determined without regard to, or special consideration for the sex of the applicant or member.

PROFILE SERIAL	X PHYSICAL WORK CAPACITY
1.	Able to perform maximum heavy duty over prolonged periods (as demonstrated by a lift of 70 pounds to a height of six feet).
2.	Able to perform sustained moderate duty over prolonged periods (as demonstrated by a lift of 40 pounds to elbow height).
3.	Able to perform standard light duty over normal work periods (as demonstrated by a lift of 20 pounds to elbow height).
4.	a. Initial Profile: (1) Enlistment. Below minimum standards for induction. (2) Appointment. Below minimum standards for commission.

b. Revision of profile, all AF personnel: Medically unacceptable for worldwide service, including remote and isolated duty [16:5-4].

In January 1976, subjective "X-Factor" testing (Physical Work Capacity) of recruits began in the Armed Forces Examining and Entrance Stations (AFEES). This required only a doctor's estimate of an individual's ability to lift the required weight as a prerequisite for entry into a particular AFSC. In March 1976, "X-Factor" testing was expanded to include objective testing of the individual's actual ability to lift the weight requirements identified for the individual's AFSC (6:10).

> On the second day of basic training, the "X-Factor" rating is verified by having the enlistee actually lift a 70, 40, or 20 pound weight one time. If there is a different result upon actually measuring the one-time lift capability, the classification change, if any occurs on the fourth day of basic military training [7:4].

"X-Factor" testing as the single determining factor in evaluating an enlistee's physical ability to satisfy the strength and stamina requirements for his or her AFSC fails to evaluate other important factors that seriously effect job performance and satisfaction (6:10). As reported by the Deputy Inspector General for Inspections and Safety:

> We conducted field tests to evaluate the ability of men and women to perform tasks associated with aircraft and missile maintenance. Sixty-six women and 75 men attempted a total of 540 tasks which were representative of six maintenance AFSCs (31XXX, 32XXX,

42XXX, 43XXX, 44XXX, and 46XXX). Men completed 99 percent of the tasks they attempted; women completed 68 percent. The principal reasons for failure were lack of strength, stamina, and reach which could not be overcome by mechanical aids. Workers 66" and taller experienced fewer problems than shorter workers 6:9 .

...our analysis of maintenance tasks indicated that height...and...other factors such as reach, size, and finger dexterity may also be significant in the maintenance and other fields. These are not now included in classification or enlistment standards [6:10].

It is important to correctly assess and develop a more comprehensive and valid assessment of the job requirements and job-related constraints for each AFSC. In the absence of valid personnel physical capability assessment and job-related constraints/requirements, one or more of several outcomes normally occurs:

(1) The lack of job satisfaction upon the part of the individuals within the AFSC who are not physically capable of performing the required tasks.

(2) The possibility of physical injury resulting from performing tasks which are actually beyond the individual's physical capability may occur.

(3) The increased training costs associated with the retraining of individuals who are physically unqualified to perform the required tasks into another AFSC.

(4) The increased cost due to personnel separating from the service prior to the Air Force recovering its investment in them.[1] (7:4).

[1]Approximately 25 percent of enlistees do not complete two years of military service (7:4).

Air Force maintenance specialties possess both common as well as unique physical demands which personnel assigned to that Air Force specialty must satisfy in order to effectively and efficiently perform the job or task requirements. Where it is obvious that the physical demands exceed man's capabilities, mechanical devices have been provided to augment man's physical characteristics in order to assure task completion (6:9). However, each individual possesses a unique set of physical characteristics (strength, stamina, muscular coordination, reaction time, weight, energy, etc.) which may not necessarily satisfy the physical demands required to successfully accomplish a particular maintenance task even with the use of existing mechanical aids (4:19).

Prior to 1972, men were predominantly assigned to maintenance Air Force specialties with little regard to the physical demand of the maintenance specialty. Only a small portion of the male work force were unable to adequately perform the required maintenance tasks (7:1). The supervisor of the shop was able to selectively qualify and use his assigned personnel on each maintenance task. The male who did not possess all the physical attributes necessary to satisfy the physical demands imposed by the maintenance specialty, was still able to adequately perform in his assigned Air Force specialty. However, this relatively minor problem of personnel being assigned to a maintenance

specialty who do not possess the needed physical characteristics to satisfy the physical demands of work is approaching significant proportions because of the introduction of women into the industrial/maintenance Air Force specialties (7:1). It has been adequately documented by the Comptroller General of the United States (4) and the Deputy Inspector General for Inspection and Safety, USAF (6) that women who do possess the physical characteristics which match the demands of the work perform those maintenance tasks equally as well as men. However, proportionately more women do not possess the required physical characteristics required to perform the maintenance task and mission effectiveness could be seriously affected if a significant portion of the work force was made up of women (4:19; 6:9).

The problems women are having in performing satisfactorily in the skilled trades is a result of the introduction of women into work that has been characteristically performed and designed to be accomplished by a male work force. Tools, equipment and work tasks have been designed to accommodate ninety-five percent of all males who are generally stronger and larger than females. Because jobs are designed to accommodate ninety-five percent of all males, tasks in heavy work AFSCs are often physically out of the reach of many women (1:3). Some women are physically capable of performing these jobs, therefore, women

as a group cannot be denied work in those AFSCs that are physically demanding if they possess the required physical characteristics (7:1). The task at hand is to develop objective physical and operational standards for the Air Force Specialties in relation to strength, stamina, and operational performance criteria, and to develop a personnel assignment/classification system which permits assignment of male and female personnel to AFSCs based on the individual's physical capacity to perform the required work.

Air Force Research in Developing Physical Demand Profiles and Personnel Assignment --Classification System

The Comptroller General of the United States in its report to Congress entitled Job Opportunities for Women in the Military: Progress and Problems, has recommended the Secretary of Defense require the military services to:

> Develop physical and operational standards for specialties where either is a factor in effective performance.
>
> Develop standards for measuring the ability of personnel to satisfy strength, stamina, and operational performance requirements for specialties where such attributes are factors in effective performance [4:26-27].

The events leading up to these recommendations have been discussed in the background and justification section of this chapter. The Air Force, in response to DOD, GAO and other agencies, has directed the Aerospace Medical Research

Laboratory, Human Engineering Division (AMRL/HED), Wright-Patterson AFB, Ohio, to develop physical and operational standards for Air Force Specialties (AFS) and to develop standards for measuring the ability of personnel to satisfy strength, stamina, and operational performance requirements (4:26-27). AMRL/HED has contracted for a design study to determine methods for establishing criteria for assigning personnel to Air Force jobs requiring heavy/very heavy work. The objectives of this design study are to define procedures and methods for determining:

> Physical strength and endurance requirements of selected Air Force Specialty Codes;
>
> Objective tests for measuring an individual's maximum safe work capability (strength aptitude[2]);
>
> Equipment and procedures for measuring strength aptitude in a feasible and cost effective manner;
>
> Validation of the physical requirements of the jobs, the objective tests, and the test equipment [7:2].

These objectives represent four basic phases in the test development and validation process. Phase I of the design study requires the development of a "...detailed, integrated method for surveying and assigning quantitative values for the physical strength and endurance which will be required of an individual performing the job [7:11]". Assigning quantitative values must be accomplished using physical units of measure rather than arbitrary units such

[2]Strength Aptitude is defined as a general suitability for physical exertion and endurance (7:1).

as rating scales. This represents a unique departure from traditional job analysis which has centered upon increasing production of the individual performing the job, in that the job is to be evaluated and units of stress assigned to significant work elements, and then these same units of stress would be used to evaluate an individual's capability via placement tests (7:11).

Phase II constitutes the development of a method for establishing objective strength aptitude tests which can be administered at the Armed Forces Examination and Enlistment Stations and at the Air Force's Basic Military Training Center. These tests must accurately determine an individual's maximum safe physical capability to perform effectively the jobs defined under Phase I (7:13).

Phase III represents defining the equipment used in strength aptitude testing to (1) classify work stress requirements of AFSCs in Phase I, (2) perform objective strength aptitude tests of Phase II, and (3) validate the assignment tests of Phase IV (7:17).

Phase IV represents the validation of assignment criteria developed in Phase I, II, and III (7:18).

RESEARCH OBJECTIVES

There are several indirect techniques available for the job analyst to measure the demands of a job. These techniques rely principally upon the analyst monitoring the

job and annotating observed physical demands on a worksheet, based on some criteria consistent with the intended use of the data obtained. The costs associated with these techniques become prohibitive when one realizes the magnitude of an undertaking to quantify the physical demands of over 290 Air Force Specialties. Consequently, alternative methods are needed which will quantify an Air Force Specialty's physical demands, and also be cost effective.

This research is being done in coordination with AMRL/HED relative to Phase I, the analysis of AFSCs to quantify the degree of heavy/very heavy work requirements of an AFSC. The hypothesis of this research is that incumbent personnel can accurately assess and assign quantitative values to the physical demands of their AFSC. The use of arbitrary rating scales and other such devices only serves to substitute non-quantitative data for equally obtainable quantitative data. The objective of this research is to evaluate whether or not military personnel serving in an Air Force specialty can provide the necessary data required to quantify, in terms of physical units of measurement, the physical demands of their AFS.

RESEARCH QUESTION

To what degree of accuracy can military personnel estimate, in terms of physical units of measurement, the physical demand of their Air Force Specialty?

Chapter 2

LITERATURE REVIEW

An extensive literature search was conducted through the Defense Documentation Center for Scientific and Technical Information (DDC), the Department of Defense Logistics Information and Exchange System (DLSIE), the Air Force Aerospace Medical Research Library, WPAFB, and local universities and public libraries to ascertain the current state of the art of developing physical demand profiles which describe the physical strength and stamina requirements of jobs. Extensive research has been accomplished in the psychological and skill aspects of Air Force Specialties. However, little research has been accomplished to quantify or predict the strength and endurance requirements of personnel assigned to maintenance jobs. Many job analysis disciplines were found that directly approach the subject of identifying job physical demands. Few, however, attempt to quantify the job in terms of actual physical measurement. The "Specific Method" developed by Mr. Hanman (10) assigns subjective values to physical abilities/attributes individuals must possess in order to successfully perform a given job. In a similar manner, the job analysis techniques developed by the Advanced Research

Resources Organization (1) relate to physical abilities analysis based on nine physical abilities which are subjectively rated on the basis of definition of these abilities, charts and rating scales.

The information presented in the Motion and Time study is discussed since it is the basis of all job analysis techniques. In the discussion concerning human engineering as it relates to the Air Force, some additional information is provided to insure that the reader understands the process of determining personnel manning requirements and duties/task analysis in relation to the physical demands of the task. In Chapter 3 of this thesis, the procedures which will be used to analyze the physical demands of the work will be discussed in detail.

MOTION AND TIME STUDY[3]

> The term motion and time study refers to a broad branch of knowledge dealing with the scientific determination of preferable work methods with the appraisal, in terms of time, of the value of work involving human activity, and with the development of material required to make practical use of these data [17:1].

The Motion Study (or work design) aspect consists of a variety of procedures for the description and scientific analysis of work methods, including the human activity

---

[3]The terms work simplification, work study, work standardization, work measurement, time study, standard work, motion study, methods research and other such terms are often used to describe parts of the field, or to describe the entire field (17:23).

needed to perform each step, in order to determine the most efficient work methods. The criteria for the preferable work method is normally a monetary incentive. However, effectiveness of activity, ease of human effort, economy of time and materials, and a variety of other factors often take precedence (17:1). Time study (or work measurement) consists of a variety of procedures for determining the amount of time required under standard conditions of measurement for tasks involving some human activity (17:1).

The general application of motion and time study has principally been to maximize productivity from existing natural and human resources. However, the basic procedure of work measurement is as relevant to the measurement of the physical strength and stamina required as to the measurement of the time required to perform an operation. The basic procedure of work measurement can be related to the measurement of physical demands for a given task as follows:

SELECT the maintenance task to be studied.

RECORD all relevant data relating to the task to be accomplished, the method of accomplishment, tools, and equipment required, and the elements which require physical demands.

MEASURE the physical demands involved in each element in terms of time, force, and distance.

COMPILE or sum each component identified in the analysis scheme.

DEFINE precisely the series of activities for which the physical demand profile has been compiled (12:218).

In the next chapter, the modified basic procedures of work measurement will be expanded into a detailed procedure for identifying and measuring the physical demands of an Air Force maintenance AFSC.

HUMAN ENGINEERING[4]

Human Engineering is "...a branch of applied science aimed at matching machines and tasks with the abilities of their human operators [3:1]." The objectives of Human Engineering are to design things so people can use them effectively and to create an environment that is suitable for human living and working (15:vii).

> The need for human engineering in the national defense is based on the fact that the science of man and his capacities must keep pace with technology if military effectiveness is to be achieved. Machines cannot fight alone; they require men to operate and maintain them. The task of human engineering,...is to get the best from man in the operation of the highly complex equipment produced by modern technology. Human engineering proceeds on the assumption that the

---

[4]The terms "Human Engineering" and "Human Factors Engineering" are for all practical purposes synonomous in the United States. In Europe and England, the term "Ergonomics" is generally accepted as being identical to "Human Engineering". Other terms used at times in the United States which are essentially equivalent to "Human Factors Engineering" are: "biotechnology", "biomechanics," and life science engineering (2:11-12).

capacities of man develop within certain limits and that by adapting the design of equipment to these capabilities, a more effective system will result [11:DH2A1,1].

Air Force human engineers collaborate with hardware engineers and designers in order to develop new and improved man-equipment interfaces that simplifies the operator's task and increases the probability of mission success. The successful design of equipment for human use requires consideration of man's basic characteristics and capacities. Therefore, the applied research programs conducted by human engineers investigate:

(1) Sensory and perceptual capacities.
(2) Motor skills, including mobility, coordination, and muscular strength.
(3) Information-handling and decision-making.
(4) Body dimensions, reach, and workspace requirements.
(5) Capacity for performing under conditions of stress, speed, fatigue, and other unusual environments.
(6) Methods for analyzing complex man-machine systems [11:DN2A1,2-3].

Air Force Systems Command's Personnel Subsystems design handbook (11) provides weapon system and equipment designers, human engineers, and job analysts the necessary guidance to determine personnel requirements for Air Force systems. In developing the personnel requirement data, the subject of physical demands placed upon operations and maintenance personnel is addressed. In order to determine the types and numbers of Air Force personnel required for system operation, maintenance and control, "... a detailed

analyses of the system equipment, and other factors having a bearing on personnel identification or manning for the system [11:DN4C1,1]" is performed. System analysts accomplish the following tasks in order to provide valid personnel data for the Qualitative and Quantitative Personnel Requirements Information Report (QQPRI):

1. Determine the function of each subsystem and major component, and its relation to the total system.
2. Develop operational and maintenance function flows.
3. Determine, in total, the duties and tasks that will be required for operation, maintenance, and control of the system.
4. Develop time, location, and frequency information for each duty and task.
5. Relate aerospace ground equipment (AGE) items to duty and task information, as well as provide QQPRI data for operation, maintenance, and control of AGE.
6. Delineate problems and conditions which may cause errors in task performance or hazards to personnel and equipment, and delineate other task characteristics that impose unique personnel training, or biomedical requirements [11:DN4C1,1].

Of special interest to this research effort is the Duty/Task Analysis Worksheet (See Figure 1). The purpose of this suggested worksheet is to identify six elements of information required for each task:

1. How restrictive is the environment in which the task is performed?

2. What characteristics of the equipment either facilitate or hinder task performance?

3. What are the mental demands of the task?

4. What are the physical demands of the task?

5. How hazardous is task performance?

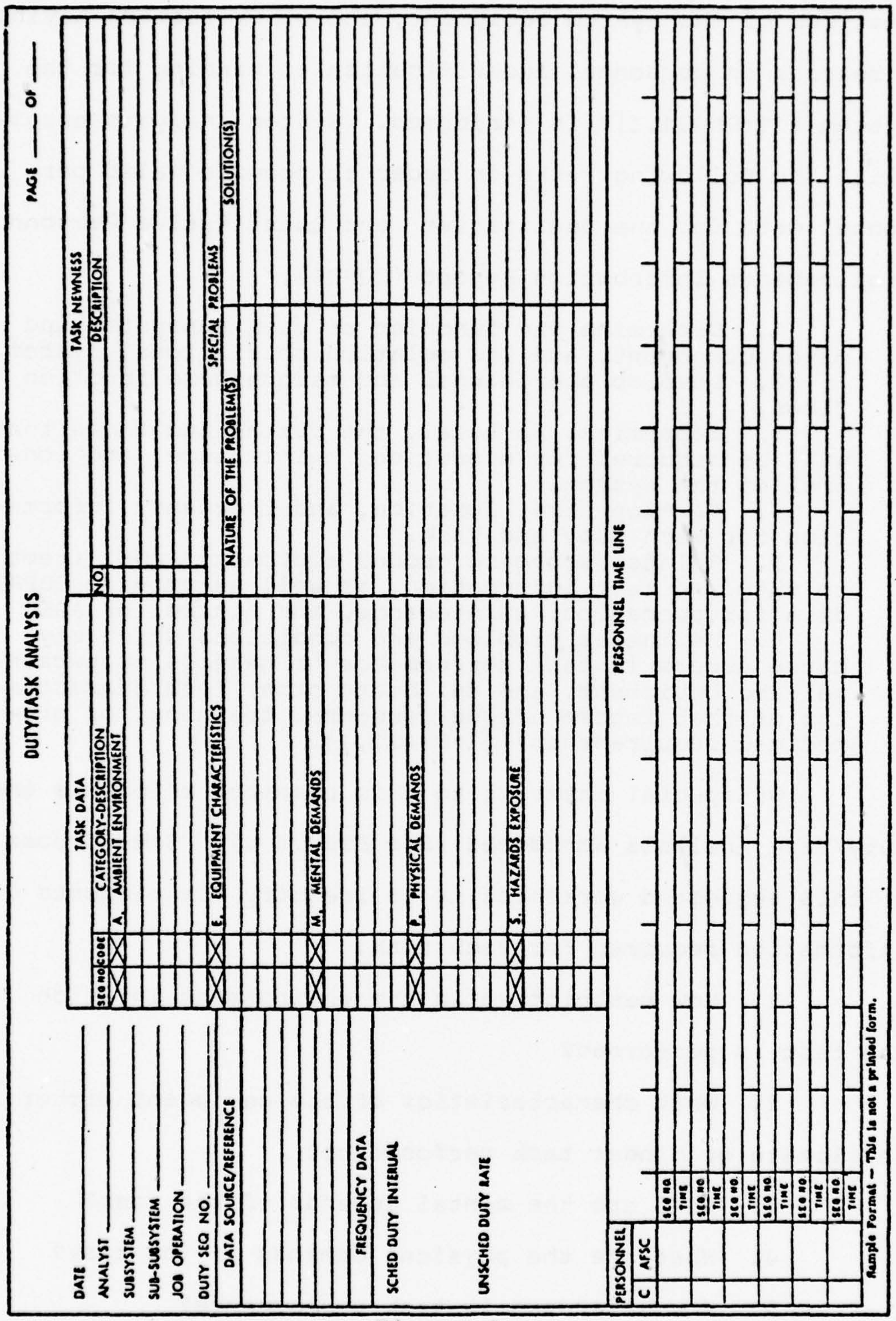


Figure 1
Duty/Task Analysis Worksheet

6. How critical is correct performance of the task to system performance or mission success (11:DN4C3,11)? In completing the physical demands portion of the Duty/Task Analysis Worksheet, the analyst evaluates

> ...task requirements in terms of depth perception, color vision, visual acuity, handling, feeling, reaching, jumping, balancing, standing, stooping, running, etc. The following are some suggested guidelines:
>
> a. CODE 1 requires little expenditure of energy, minor stamina; little or no special dexterity or precision of movement involved; imprecise manipulations, noncritical and coarse motions, readily learned by demonstration; simple use of sensory organs; coarse, noncritical perceptions, such as sensing imprecise indications, distinguishing between primary colors, differentiating coarse texture from smooth or between ODOR/NO ODOR, NOISE/NO NOISE, MOVEMENT/NO MOVEMENT, TASTE/NO TASTE, etc.
>
> b. CODE 2 requires moderate expenditure of energy; coordinated and fairly precise physical motions; steady response to sensory cues; accurate and coordinated perception of one or more fixed or variable indications, such as quantitative instrument readings; distinguishing between relative positions of objects, shapes of objects, colors, kinds of taste, differences in weight, relative frequency and rates of movement, etc.
>
> c. CODE 3 requires either a high level of energy expenditure and stamina or a high degree of dexterity, precision, and coordination of movement, with complex, quick, and varied responses to sensory cues; physical dexterity of a critical, exact, or variable type that must be practiced; motions involving crucial responses; perceptual ability involving critical, precise, or coordinated sensing of one or more fixed or variable indications, such as distinguishing qualitative indications of an object, relative motion, degrees of comparison, simultaneous or critical event, differences in amounts of pressure, amounts and kinds of odor, amounts and kinds of taste, shades and brilliance of colors, volume of sound, the frequency, rates, and direction of movement, etc [11:DN4C3,14].

The information presented demonstrates that Air Force human engineering does accomplish an evaluation of a task's demands during system development. In relation to the task's physical demands, the evaluation identifies those elements of the task which constitute significant physical demand in a very general and subjective manner with no real attempt to quantify, in terms of actual physical units of measurement, the various elements of a task which require significant physical demands. Rather, the working data is used for collecting the necessary information to predict personnel and manpower requirements for systems under development, and in preparing the actual position descriptions and manning estimates submitted to the Air Force in the formal Qualitative and Quantitative Personnel Requirements Information Report (11:DN4C4,2). In addition, the codes (1, 2, 3) used in completing the physical demands portion of the Duty/Task Analysis worksheet are extremely broad in scope and subjective in definition. Due to the manner in which these codes are defined, they do not provide an adequate means for assessing required personnel physical demands, nor a means for establishing a physical demand profile for an Air Force specialty.

STUDIES TO DEVELOP PHYSICAL DEMAND PROFILES FOR AIR FORCE AFSCs

In late 1975, the Occupational and Manpower Research Division, Air Force Human Resources Laboratory (AFHRL), Lackland AFB, Texas, conducted research directed towards the development of physical demand profiles for Air Force Specialties.

> The purpose of the study was to investigate certain physical characteristics of jobs in terms of the dexterity, muscular coordination, and sensory discrimination required in airmen occupations...The specific objectives were two-fold:
> 1. To determine whether or not physical demands of jobs could be readily reported by job incumbents.
> 2. To derive and compare the physical demand profiles for each of the career ladders selected for the study [13:5].

In conducting the study, 133 physical demands of jobs were identified through an extensive literature review covering work requirements of airmen specialties.

> Ten primary physical demands or factors were selected for study. These were chosen upon the premise that an airman could be assessed of his qualifications for each demand at the point of entrance into the Air Force. In addition, five lifting demands ranging in increments from 1-20 pounds to 81 pounds or over were selected [13:5].

The ten primary demands chosen for study were: hand-arm movement, finger dexterity, body strength, hand-arm strength, physical effort, eye-hand coordination, body coordination, hand-arm steadiness, precision, and reaction time. The five lifting requirements cover the range of lifting requirements from heavy lifting to relatively little lifting effort. Two five-point scales were used to

rate each of the ten physical demands in relative terms, and to rate the lifting requirements in relation to the frequency of the act (13:5-6).

The four airmen career ladders chosen were: Avionic Instrument Systems Specialist, 325X1; Instrument Repairman, 422X0; Aircraft Loadmaster, 607X0/A; and Aircrew Life Support Specialist, 922X0/B. These airmen career ladders were chosen because they appeared to require different physical demands. The survey was conducted by a questionnaire (13:6).

The researchers drew the following conclusions from their study:

> Reliable physical demand measures were obtained for four career ladders. With the exception of the hand-arm strength measure, significant physical demand differences were found between the career ladders. The most extreme differences among ladders were noted for precision and reaction time requirements.
>
> With variations, the profiles for the Aircraft Loadmaster and Aircrew Life Support ladders demand higher amounts of physical strength (Loadmaster jobs also required fast reaction time and greater body coordination). The profiles for the Avionic Instrument Systems and Instrument Repairman ladders show higher amounts of required hand-arm movement, finger dexterity, eye-hand coordination, and precision.
>
> For all four career ladders, a high percentage of incumbents reported a very frequent requirement for light lifting. However, an unexpectedly large number of Aircrew Life Support and Aircraft Loadmaster incumbents reported very heavy lifting requirements.
>
> Substantially higher profile correlations were obtained between subgroups within career ladders than between airmen with similar tenure in other ladders. Results support a conclusion that career ladders have unique physical demands which can be inferred from job incumbent responses.

> An important task remains: that is, to validate incumbents' physical demand ratings. Future projects in this area should attempt to identify, define, measure, and validate additional physical demands. In addition, various physical demands should be evaluated as task rating factors for identifying specific career ladder requirements. Certain other methodological changes to the present approach may also be examined. For example, changes in the demand factors of lifting scales, assessing accuracy of a job incumbent's recall of requirements, or identifying body positions in lifting may be investigated further [13:14].

The researchers obtained "statistically reliable" physical demand measures reported by job incumbents, however, the validity of incumbent's physical demand ratings still require validating. Incumbent personnel rated the "whole job" in completing the questionnaire in that no attempt was made to have personnel identify or rate various tasks associated with their AFSC, nor was there any attempt to identify or rate the elements of the task which require significant physical demands. Furthermore, incumbent personnel were constrained in their responses they provided due to the generality and subjectivity of the rating scales used, and because they rated all jobs performed by the AFSC in relation to only ten physical demands which may or may not be present in their work. The purpose of our research is to assess how accurately incumbent personnel can assign quantitative values, as opposed to arbitrary rating scale values, to the physical demands of the tasks performed in their AFSC.

JOB PLACEMENT AND PHYSICAL CAPACITIES

The idea of placing men and women in jobs they are physically qualified to perform is not new. This is especially true in relation to the elderly and those workers who are referred to as disabled. Mr. Bert Hanman in his book, Physical Capabilities and Job Placement, provides a summary of the theory and practice of job placement, principally of disabled workers. Furthermore, he has developed a plan which he refers to as the "Specific Method". This plan established the procedures necessary for job analysis, analysis of worker physical capabilities, and job placement.

> ...The application of the plan involves the participation of three persons, or three groups....First, Job Analysts, who prepare specific information on the physical and environmental demands of jobs...Second, industrial physicians, who prepare specific information on the physical and environmental capacities of workers....and third, placement officers, who relate the workers physical abilities to jobs by...selecting the job which is best suited to the worker's skills and physical abilities [10:121].

Only the work of the job analysts is relevant to this thesis and will be discussed in detail. The other two areas (individual evaluation and placement) will be summarized briefly.

Figure 2 is an example of the worksheet used by the job analysts to record the physical demands of jobs.[5]

---

[5]The worksheet was developed over a seven year period and has been used to analyze over 5000 jobs (10:69).

PHYSICAL DEMANDS ANALYSIS WORKSHEET

Job Title: ____

Job Location: ____

Physical Factors:

	No.		Factor	
___	1	1- 5	Lifting (Pounds) Includes pushing and pulling effort while stationary.	
___	2	6- 10		
___	3	11- 25		
___	4	26- 50		
___	5	51-100		
___	6	100+		
___	7	1- 5	Carrying(Pounds) Includes pushing and pulling effort while walking.	
___	8	6- 10		
___	9	11- 25		
___	10	26- 50		
___	11	51-100		
___	12	100+		
___	13	R	Fingering	
___	14	L		
___	15	R	Handling	
___	16	L		
___	17	R	Below Shoulders	Reaching
___	18	L		
___	19	R	Above Shoulders	
___	20	L		
___	21	R	Throwing	
___	22	L		
___	23		Sitting	
___	24		Total Time on Feet	
___	25		Standing	
___	26		Walking	
___	27		Running	
___	28		Jumping	
___	29		Legs Only	Climbing
___	30		Legs and Arms	
___	31	R	While Sitting	Treading
___	32	L		
___	33	R	While Standing	
___	34	L		

	No.	Factor	
___	35	Stooping	
___	36	Crouching	
___	37	Kneeling	
___	38	Crawling	
___	39	Reclining	
___	40	Twisting	
___	41	Waiting Time	
___	42	Far-Snellen	Seeing
___	43	Near-Jaeger	
___	44	Color	
___	45	Depth	
___	46	Hearing	
___	47	Talking	
___	48	Other: ___________	
___	49	Other: ___________	

Figure 2

Physical Demands Analysis Worksheet

PHYSICAL DEMANDS ANALYSIS WORKSHEET

(Part 2)

Environmental Factors:

____	50	Inside
____	51	Fair Weather
____	52	Wet Weather
____	53	Hot °F
____	54	Cold °F
____	55	Sudden Temperature Changes
____	56	Humid
____	57	Dry
____	58	Moving Objects
____	59	Hazardous Machinery
____	60	Sharp Tools or Materials
____	61	Cluttered Floors
____	62	Slippery Floors
____	63	High Places
____	64	Electrical Hazards
____	65	Exposure to Burns
____	66	Explosives
____	67	Radiant Energy (Kind): ____________
____	68	Poor Lighting
____	69	Poor Ventilation
____	70	Toxic Conditions (Kind): ____________
____	71	Wet Quarters
____	72	Close Quarters
____	73	Vibration
____	74	Noise
____	75	Working With Others
____	76	Working Around Others
____	77	Working Alone
____	78	Shifts
____	79	Other: ____________
____	80	Other: ____________

Figure 2

Physical Demands Analysis Worksheet (cont)

The worksheet identifies 80 factors which represent practically all the factors it is possible to encounter in any work situation (10:121). The job analyst completes the worksheet in the following manner:

1. With the exception of the sensory factors (42-47), the analyst records the maximum number of hours each factor is required during the work day. When the factor is required less than one hour per day, fractions of an hour are recorded in multiples of 1/4 of an hour (i.e. 1/4, 1/2, 3/4).

2. The spaces before all factors not required by the job are filled in by the analyst with a dash (-) to show the factor has been considered but is not required.

3. Far Vision (42): The analyst determines the size of the most difficult object the job requires the worker to see at a distance of five feet or more, and the distance the object is from the worker. The analyst then refers to the Snellen, or to the Monoyer Visual Acuity Table to locate the proper notation for the far vision requirements of the work.

4. Near Vision (43): The analyst determines the size of the most difficult object the job requires the worker to see at close working distance. The size of the object is then converted into the equivalent size of printed type on near vision charts, wherein the analyst approximates the near vision requirements of the job according to the charts.

5. When the job requires sensory factors (44-47), a plus sign (+) is marked in the adjacent space meaning that the factor is required in the job.

6. In addition to recording the number of hours a factor is required, several of the environmental factors require additional information. Items 53 and 54 require the temperature in degrees Fahrenheit and Celsius be entered. The type of radiant energy (Item 67) and the kind of toxic condition present (Item 70) must be identified where applicable. In Item 78, in addition to showing the maximum length of the shift in hours, the number of the shift (1, 2, 3) is also identified (10:133-4,157).

The information accumulated by the job analyst is then used by an industrial physician who evaluates the individual seeking the position to ascertain if the work is compatable with the individual's physical limitations (10:121). The physical factors identified in Figure 2 provide a method to identify what an individual must be able to do in order to qualify for a given job. For example, the worker must be able to stand for eight hours, have the use of both right and left hands, be able to lift and carry six to ten pounds for a total of four hours per work shift, and have adequate hearing, near vision and depth perception. In effect, a job is analyzed in relation to human faculties, that is the ability to see, hear, climb, maintain various body positions, possess sufficient

body mobility, etc., in order to accomplish the job. Physical measurement is accomplished only in identifying the maximum weight an individual is required to lift and/or carry during the work shift.

The direct application of Mr. Hanman's physical demands analysis will not provide the data necessary to answer the research question because the analyst does not quantify the task in terms of physical units of measurements, nor does the individual(s) performing the work provide estimates of the physical requirements of the job. Mr. Hanman's "Specific Method" is none the less significant in that it represents a full-fledged attempt to develop a physical demand profile for a given job, and to assign personnel based on their ability to physically perform the required work. Many of the procedures used by the job analyst in applying the "Specific Method" are applicable to this thesis and will be used in developing the research design identified in Chapter 3.

PHYSICAL ABILITIES ANALYSIS

The Advanced Research Resources Organization of Silver Springs, Maryland has developed a technique entitled "Physical Abilities Analysis", which has been used to develop profiles of physical requirements for such jobs as fireman and sanitation man of large metropolitan cities and also for various jobs in the telephone company.

The "Physical Abilities Analysis" technique develops a physical profile for a given job by assessing the extent to which a job requires an individual to use nine physical abilities (8:10). These abilities are:

Dynamic Strength-...the ability to exert muscular force repeatedly or continuously over time. It represents muscular endurance and emphasizes the resistance of the muscle's fatigue. The common characteristics of tasks involving this ability is of the power of the muscles to propel, support or move the body repeatedly or support it for prolonged periods.

Trunk Strength-...limited dynamic strength factor ...particularly the abdominal muscles.

Static Strength-...The force an individual can exert against external objects (such as in lifting heavy weights or pulling heavy equipment). It... represents the maximum force which an individual can exert, even for a brief period, where the force is exerted up to some maximum effort.

Explosive Strength-...the ability to expend a maximum of energy in one or a series of explosive acts. This ability is distinguished from the other strength factors in requiring effective mobilization of energy for a burst of effort, rather than continuous strain...

Extent Flexibility-...the ability to flex or stretch the trunk and back muscles as far as possible in either forward, lateral, or backward direction. This would be involved in tasks which require suppleness and reaching and stretching activities.

Dynamic Flexibility-...the ability to make rapid, repeated flexing movements in which resilience of the muscles in recovering from strain or distortion is critical. This would be involved where an individual has to continuously bend up and down in whatever activity he's involved, in contrast to having to stretch a maximum distance.

Gross Body Coordination-...the ability to coordinate the simultaneous actions of different parts of the body or body limbs while the body is in movement. This ability has been often called agility.

> Balance or Equilibrium-...the ability of an individual to maintain his equilibrium despite forces pulling off balance; this ability is used, for instance, in walking on narrow surfaces or on ledges.
>
> Stamina-...Sometimes...called "cardio-vascular endurance"...involves the capacity to continue maximum effort requiring prolonged exertion over time [9:29-35].

The "Physical Abilities Analysis" technique requires the use of a manual which contains and describes the use of nine rating scales, one for each of the physical abilities. The manual contains definitions of each of the nine abilities and charts for differentiating one ability from another. Each of the abilities are rated on the basis of a seven-point rating scale with one being the lowest amount of a particular ability required and seven representing the greatest amount. The analyst, in applying the procedures, seeks to answer four questions. First, is the ability required or not required on the job? Second, if in the opinion of the analyst the ability is required to normally accomplish the work, how much of the ability is needed? Third, if the ability is required to perform any special task, how much of the ability is required? And fourth, how often must the worker do these special tasks? When these questions are answered, the job will have been described in terms of the abilities needed to do the job. In effect, the rater, in observing a job, looks at the tasks involved and subjectively places the job somewhere on the scale with respect to the provided

definitions and examples for each of the physical abilities described (8:10,24).

This research seeks to determine if measurement of the job's physical demands can be accomplished from the quantitative estimates of the job's demands provided by personnel working in the AFSC. The application of the procedures identified in the "Physical Abilities Manual" provides little assistance to this research since no effort is made to even measure the job's physical demands. Rather, rating scales are used to subjectively assess the degree to which the nine physical abilities are required in the performance of the work. Further, the ratings consider the job or task as a whole whereas our proposed research seeks to quantify at the sub-task/task element level.

Chapter 3

RESEARCH DESIGN AND METHODOLOGY

The research design presented in this chapter is drawn from the techniques of Motion and Time Study, Mr. Hanman's Specific Method, and the research of the Occupational and Manpower Research Division (OMRD) of AFHRL. Motion and Time Study (primarily work measurement) (17) and the Specific Method (10), provide the techniques that were used to identify and quantify an AFSC's physical demands during the observation portion of this research. The interview portion of this research is essentially based on the conclusions obtained from the research conducted by OMRD/AFHRL.

The OMRD researchers concluded that reliable physical demand measures were reported by incumbent personnel (13). If incumbent personnel can provide reliable physical demand measures which were based on arbitrary rating scales, it is not unreasonable to assume that incumbent personnel can also accurately assess and assign quantitative values when the quantitative measures are adequately defined and understood. The objective of this research is to evaluate the ability of military personnel performing duty in an Air Force specialty to assess and quantify the

physical demands of the AFS. To achieve this objective, the researchers (1) interviewed personnel assigned to an aircraft avionics maintenance AFSC (328X1) and recorded the incumbent's quantitative evaluation of the task's physical demands based upon his estimation of the force/weights, distance and time required to perform a given task, and (2) validated the incumbent's estimates by actually observing and quantifying the AFSC's physical demands through job analysis techniques.

In this chapter, the research design will be explained by providing:

1. the criteria used in selection of the pilot study AFSC;
2. the universe, population and sample;
3. the method used to identify the task an AFSC performs;
4. the development of the interview and observation instrument;
5. the definitions of the terms used in accomplishing this research;
6. the interview and observation designs that were used to quantify physical demands;
7. the statistical techniques used in evaluating obtained data; and
8. the limitations and assumptions associated with this research.

CRITERIA FOR SELECTING PILOT STUDY AFSC

In order to validate the incumbent's assessment of a task's physical demands, one aircraft maintenance specialty which satisfied the following criteria was selected for the pilot study:

1. There must exist a broad range in the physical severity of tasks among the maintenance requirements; that is, work in the AFSC must require the application of light, medium and heavy forces to be exerted by the individuals in performing various maintenance tasks.

2. Personnel assigned to the pilot study AFSC should provide a representative cross-sample of all personnel who are presently assigned to the AFSC.

3. The AFSC should have broad application across several different aircraft systems and use similar techniques, tools and equipment to permit follow-on studies to investigate differing demands due to aircraft system type.

DESCRIPTION OF UNIVERSE, POPULATION AND SAMPLE

Universe

The universe consists of all enlisted personnel working in Air Force maintenance specialties.

Population

A survey of the units located at Wright Patterson AFB, Ohio, revealed that the 32XXX AFSC satisfied the criteria for selecting a pilot study AFSC. This career field was chosen as the pilot study AFSC after interviewing supervisory personnel working in the career field who identified tasks having a broad range of physical severity and which they considered to be typical of those performed throughout the Air Force on similar aircraft systems.

Selection of Population Sample

Air Force Specialty 328X1, including the Avionic Navigation Systems Specialist (32851) and the Avionic Navigation Systems Technicians (32871), was chosen as the pilot test AFSC after an in depth interview of work center supervisory personnel, an evaluation of the physical demands of the AFSC, the work center mission requirements, and the work center ability and willingness to support this research. Personnel working in this AFSC experience a broad range of physical severity in accomplishing maintenance tasks on three different aircraft systems (C-135, C-141, and T-39 aircraft) located at Wright Patterson AFB, Ohio. A total of nineteen personnel were permanently assigned to this work center (sixteen of which were interviewed for this study) and it was assumed that they

provided a typical cross-section of personnel presently holding the 328X1 AFSC. This assumption was based on past duty assignments and varying aircraft systems on which the assigned personnel have performed maintenance (See Table 1).

DETERMINATION OF TASKS AN AFSC PERFORMS

The Air Force Specialty Code's Specialty Training Standard was used as the primary source for identifying those tasks on which observations and interviews were performed in order to characterize and measure/estimate the physical demands of the AFSC. Air Force Specialty Training Standards (STS):

> ...are the official Air Force specifications for training. They describe an AFS in terms of the tasks and knowledge which airmen in that specialty are required to perform or know on the job. STSs correlate with and expand on the AFS description contained in AFM 39-1. An STS is a detailed, printed breakdown of a particular AFS into many individual tasks and knowledges....All significant job elements are reflected...[5:3-2].

Furthermore, Air Force Manual 50-23, "On-The-Job Training", defines a "task" as "a unit of work activity which forms a significant part of a duty. Task statements may be found under duties listed in AFM 39-1 and on STSs... [5: A4-3]." Since all significant elements of the task, or work activity performed by an Air Force specialty were found in the Specialty Training Standard for the AFSC, the document provided for identification of 1) administration,

Table 1

Respondent Background

Respon-dent	Skill Level	Time in AFSC 328X1	Operational USAF/ANG, Aircraft Upon Which Respondent has Performed Maintenance
1)	9	26	T-37, T-38, F-5, C-130, C-141, KC-135, B-52, C-119, T-33, T-39, F-100, F-101, F-4, F-102, F-106, F-104.
2)	7	24	C-141, KC-135, C-119, C-130, T-39, B-52, CH-53.
3)	7	23	Same as Respondent #1.
4)	7	19	C-141, KC-135, KC-97, C-130, C-7A, 02A, OV-10, UH-1, T-37, T-33, C-119, C-12, RF-4C, F-4, B-52, B-57, CH-53.
5)	5	3	C-141, KC-135, T-39, B-52, CH-53.
6)	5	2	C-141, KC-135, T-39, C-130, F-4, T-33, H-3, CH-53, T-38.
7)	5	24	C-141, KC-135, T-39, KC-97, F-4, F-100, F-105, F-5, T-38, T-33, T-37, C-123, C-119.
8)	5	4½	C-141, KC-135, F-106, T-33, T-39, C-130, CH-53, T-37, T-38, H-3, C-123.
9)	7	4	C-141, KC-135, T-39, T-38, T-37, T-33, C-130, CH-53.
10)	5	2	C-141, KC-135, T-39, C-130, F-4, T-33, H-3, CH-53.
11)	5	2	C-141, KC-135, T-39, T-37, CH-53, H-3, C-130.
12)	5	2	C-141, KC-135, T-33, T-37, T-39, C-130, F-4, F-101.
13)	7	16½	C-141, KC-135, T-39, C-130, F-4, F-105, T-33, H-3, CH-53.
14)	7	9	C-141, KC-135, C-130, C-123, C-7A, AC-119, A-1, O-2, OU-10, F-4, B-52, F-100, T-37, T-38, CH-53, H-3.
15)	5	4	C-141, KC-135, T-33, T-37, T-39, C-130, F-4, F-101.
16)	5	3½	Same as Respondent #15.

2) supervision and training, 3) maintenance management, 4) maintenance and 5) associated duties/responsibilities. Quantification of physical demands were accomplished on only those tasks applicable to maintenance action in this pilot study, because it was primarily in this area that physical demands were placed upon personnel (4:7).

The STS was primarily a training document used to identify an individual's training requirements, and to identify certification of the individual's competence to perform the maintenance task(s). In addition, a significant task in the STS was normally written in general terms. Consequently, the STS provided only a starting point upon which to build in identifying the maintenance tasks that constitute the work requirements of an AFSC.

In order to identify the elements which constitute an STS maintenance task statement, the STS served as a guide which was used by the work center supervisor and/or his assistant(s), in coordination with the researchers, to identify the various tasks which the AFSC performs. Three tasks were selected which, in the opinion of the researchers and the work center supervisors 1) required heavy/very heavy physical demands of the personnel performing the task[6],

[6]In performing almost any maintenance task, personnel will generally experience a full range of physical demands from light to heavy/very heavy. Consequently, the personnel interviewed were asked to estimate the forces applied, weights handled as well as the distances and times involved for all elements which were in excess of ten pounds of force/weight involved. This was done to verify if the methodology would work over the full range of physical demands.

and 2) would permit observation of the task being performed consistent with the space limitations associated with some aircraft.

Specialty Training Standard, STS 328X1, task number/statement 8f Remove and replace defective Line Replaceable Units (LRU) was sub-divided into the following individual tasks[7]:

1) Remove and Replace Receiver-Transmitter RT 289/ APN59.
2) Remove and Replace Search Radar Antenna.
3) Remove and Replace Receiver-Transmitter RT 220/ ARN21.

These tasks were then evaluated by the researchers using the interview and observation procedures explained in this chapter. The complete STS 328X1 is provided in Appendix A.

INTERVIEW/OBSERVATION INSTRUMENT DEVELOPMENT

The researchers, in coordination with and in response to the recommendations of personnel from AMRL/ HED, developed the interview/observation instrument from the aircraft system technical orders. An aircraft system technical order identifies the authorized step-by-step procedures for accomplishing essentially all maintenance tasks on any given aircraft subsystem. Technical orders

[7] Tasks not evaluated in this research effort are not identified in this list.

were used to develop the instrument because they represent a standard Air Force publication written for virtually all tasks performed on systems operated and maintained by Air Force personnel. If these publications prove capable of describing the job's tasks in sufficient detail, they could provide valuable assistance in establishing the criteria for assigning personnel to Air Force specialties requiring heavy/very heavy work.

The procedural steps required to accomplish the three maintenance tasks evaluated were entered in the activity column of the worksheet (Figure 3). A copy of the worksheet used in this research is provided in Appendix B, and technical order procedures used in developing these worksheets is provided in Appendix C.

DEFINITIONS

Throughout this research, several terms are used to describe the activity being evaluated/described. The following definitions are provided to insure understanding of the meaning of terms as they apply to this research.

<u>Carrying</u>: transporting an object, usually holding it in the hands or arms or on the shoulders [24:655].

<u>Distance</u>: the number of feet and/or inches traveled in accomplishing a given action.

<u>Frequency/Duration/Pace</u>: measures of the time dimensions of the handling task including frequency, duration and required dynamics of activity over the short term and long term [20:7-8].

OBSERVATION WORKSHEET																		Sheet ___ of ___ Date:
No. Personnel Performing Task:					Task No:						Task Element Description:							
		Force Categories									Measurements							
Activity:	Non-Signif.	Lift	Lower	Torque	Turn	Push	Pull	Carry	Hold	Other	Distance	Time	Frequency	Power	Force	Force Time	Force Distance	Remarks:

Figure 3
Interview/Observation Worksheet

Hold: to support an object by one's hand(s), arm(s), or body in order to maintain an object in a certain position.

Lifting: raising...an object from one level to another (includes upward pulling) [24:655].

Load: measure of force; pushing/pulling force requirements, mass moments of inertia; weight, etc. [20:7-8].

Lower: to let down, or to allow an object to descent under restraint.

Non-Significant Physical Demands: those physical activities required of a worker to apply forces of, or to handle loads less than ten pounds.

Physical Demands: those physical activities required of a worker in a job [20:7-8].

Physical Effort: the intermittent or continuous exertion of body muscular strength to accomplish movement or maintain positions which are tiring to the body.

Pulling: exerting force upon an object so that the object moves toward the force (includes jerking) [24:655].

Pushing: exerting force upon an object so that the object moves away from the force [24:655].

Time: the number of minutes and/or seconds required to accomplish a given action.

Torque: turning or twisting force applied to tighten or loosen an item.

Turn: to move around, or to change position by rotating, in order to achieve some desired result.

INTERVIEW AND OBSERVATION DESIGN

Interview Design

The following guidelines were followed in accomplishing personal interviews in order to obtain the

individual's quantitative estimate of the task's physical demand.

1. Personnel were selected for interview based on a) possession of a 5 or 7 skill level[8] in the AFSC, b) being STS certified as competent to perform the task, and c) having accomplished the task within the last thirty days. These three requirements insured that the personnel interviewed were familiar with the task being evaluated. For each of the three tasks, sixteen personnel were interviewed.

2. At the beginning of the interview, the purpose of the research and the manner in which the interview was to be conducted was explained to each person using the interview briefing as provided in Appendix D. While conducting the interview, the interview/observation worksheet was annotated in the following manner:
a) if the activity identified was judged to be non-significant[9], a check mark was placed in the appropriate

---

[8]Skill level. The level of qualification in an AFS depicted by the fourth digit in the AFSC as follows:
1 - Helper Level
3 - Semi-skilled Level (Apprentice)
5 - Skilled Level (Journeyman)
7 - Advanced Level (Supervisor/Technician)
9 - Superintendent [5:A4-3].

[9]Physical activities requiring the worker to apply forces of, or to handle loads of less than ten pounds were considered in this research as sendentary work and judged to be non-significant, whereas ten pounds or greater was judged significant and recorded on the interview/observation worksheet (24:A-1).

column and no other entries were made for that activity; and b) if the activity was judged significant, the appropriate force category was identified and the individual's estimate of the force was entered. The individual then estimated the distance and time over which the force was applied, and the frequency of the action. If the dimensions of time and/or distance could not be estimated because of the extremely short duration and/or distance over which the force was applied, a dash (-) was entered in the column(s).

Observation Design

The following guidelines were used in accomplishing task observations to develop the standards for subsequent comparison with respondent estimates (7:9; 12).

1. All observations were conducted in the actual work environment. The observer was present for the entire maintenance function and recorded the task's physical demands on the observation worksheet (Figure 3, page 44). Weight and force measurements were accomplished whenever possible prior to initiating the maintenance action to avoid interfering with the work in progress.

2. The observer positioned himself in a location that permitted adequate observation of the personnel and the task being performed. While monitoring the task, the observation worksheet was annotated in the following manner:

a) If the work was considered significant, separate line entries were made for each force category by inserting a checkmark in the appropriate column when the force/weight was unknown, or by entering the actual force/weight when known (Step 1). Measurement of items whose forces/weights were not previously identified was accomplished by using shop spares when available or estimated by the weights identified in equipment technical orders. All force and weight measurements were accomplished in foot-pound and pounds using either spring or platform scales.

b) The time (duration of load handling/force application) over which physical demands were required was recorded for each occurence in seconds.

c) The distance over which the force was applied was either measured or estimated to the nearest foot.

d) The frequency/number of times the force was applied was identified and recorded.

STATISTICAL TEST AND PROCEDURES

Statistical Test--Wilcoxon Signed Rank Test

The objective of this research was to determine if personnel working in an Air Force Specialty could provide the same quantified information in relation to the physical demands placed upon them as could be obtained through job analysis techniques. For each of the tasks evaluated, matched pairs of data were obtained in the form of

quantified personnel estimates and the actual requirement, or standard, for each activity associated with the three removal and replacement tasks. The parametric paired t-test was not used because the small sample size of sixteen respondents precluded the assumption of normalcy necessary for the use of the test. The Wilcoxon Signed Rank Test, a nonparametric analog of the parametric paired t-test for matched samples, was used to resolve the question of whether or not the information obtained from personnel estimates and work sampling were the same (19:675). In this research, D_i represents the normalized difference between X_i and Y_i for the ith matched pair; where X_i represents the actual or standard index for activity A_i, and Y_i represents the estimated normalized index for activity A_i (19:675).

The raw data obtained from both task observations/standard and individual estimates for a given activity A_i took the form of three variables: force/weight, time and distance. From these variables, one of four indices was computed. The four indices were:

1. Power (P) = $\frac{\text{Force x Distance}}{\text{Time}}$; when all three variables were applicable to computing the rate of doing work.

2. Force (F); when "time" and "distance" measurement/estimation were not applicable.

3. Force x Distance (FD); when the "time" variable was not applicable to measurement/estimation.

4. Force/Time (FT); when the "distance" variable was not applicable to measurement/estimation.

The four indices (P, F, FD, FT) as directly computed were comparable neither among values of the same index nor among different indices, because individual values of the indices contain different information on scales varying between activities. Consequently, it was necessary to compute D_i as a "normalized difference" with respect to activity A_i in order to perform a meaningful statistical comparison of measurement and estimation across activities.

The "normalized difference", D_i, was determined by computing the sample standard deviation (S) of the estimated index (as defined above) for activity A_i, and then computing $D_{\text{activity } A_i}$ in the following manner:

$$D_{\text{activity } A_i} = \frac{Y_{\text{estimated index of } A_i} - X_{\text{standard index of } A_i}}{S_{\text{estimated index of } A_i}}$$

So defined, $D_{\text{activity } A_i}$, was a dimensionless entity, normalized by source, i.e. with respect to a particular activity and task. These differences were then comparable, because they had been normalized by activity, as a sample drawn from the population of all such normalized

differences (17; 18:548). The Wilcoxon Signed Rank Test resolves the question of whether or not these values could have been drawn from a distribution with a zero mean (μ).

The hypothesis test associated with the Wilcoxon Signed Rank Test and this research was (19:675):

$$H_0: \mu_x = \mu_y$$
$$H_1: \mu_x \neq \mu_y$$

The null hypothesis, H_0, states that the information obtained from personnel estimates and work sampling does not differ (22:78). That is, the information obtained from actual work sampling and measurement cannot be shown to be other than the same information obtained from personnel estimates. Effectively, no information would be gained or lost through the estimation process over actual work sampling. "In terms of the Wilcoxon test, the sum of the positive ranks = the sum of the negative ranks [22:78]." The alternate hypothesis, H_1, states that the two information sources differ as evidenced by "...the sum of the positive ranks ≠ the sum of the negative ranks [22:78]." That is, the information obtained through work sampling was statistically significantly different from the information obtained from personnel estimates (19:675-6).

In using the Wilcoxon test to resolve the research hypothesis, the test statistic, R, was computed by ranking the absolute values of all $D_{\text{activity } A_i}$ from smallest to

largest. If any $D_{activity\ A_i} = 0$, the value was dropped from the set and the sample size decreased accordingly. Where ties occurred, the average value of the ranks of the items involved in the ties was used as the rank of each of the tied values. Each rank was then suffixed with the sign of the difference $D_{activity\ A_i}$ corresponding to it. The statistic R^+ represented the sum of the positive ranks, and the statistic R^- represented the sum of the negative ranks. The test statistic designated R, is the smaller of the R^+ and R^- statistics (19:675). A two-tail test, with $\alpha = 0.025$ in each tail, was performed since there existed no evidence to suggest that the rejection region would occur in either the right or the left tail. Consequently, the following decision rule was applied to the test statistic R:

> Reject H_0 at the $\alpha = .05$ significance level if R exceeds $W_{0.975}$ or R was less than $W_{0.025}$, where $W_{0.025}$ and $W_{0.975}$ are the critical values of the Wilcoxon signed rank test statistic. Otherwise, fail to reject H_0 (19:675).

The upper and lower critical value of $W_{0.05}$ was approximated by:

$$W_\alpha = [n(n+1)/4] + z_\alpha \sqrt{n(n+1)(2n+1)/24}$$

where z is the standard normal variate such that $z_{0.025} = -1.96$ for $W_{0.025}$, the lower critical limit, and $z_{0.025} = +1.96$ for $W_{0.975}$, the upper critical limit (19:724).

The assumptions associated with the Wilcoxon Signed Rank Test are:

1. Each D_i must be a continuous random variable,
2. The distribution of each D_i must be symmetric,
3. The pairs, (X_i, Y_i) $i = 1, 2, \ldots n$ represent a random sample from a bivariate distribution,
4. The measurement scale for the X's and Y's is at least interval [19:675].

The first assumption was satisfied since X_i and Y_i used in computing D_i may assume an infinite number of values dependent upon the estimated values of force, time and distance variables. The estimates of force, time and distance were unrestricted, continuous, ratio level data. The second assumption was satisfied since the probability that D_i was positive, was equal to the probability that D_i was negative. It was equally likely that an individual's estimates of the variables (force, time and distance) were equal to, less than, or greater than the standard obtained through actual measurement. Consequently, the distribution of D_i was expected to be symmetric about a zero mean. Verification of this assumption has been accomplished by plotting $D_{activity\ A_i}$ values as shown in Chapter 4. The third assumption, the pairs (X_i, Y_i), $i = 1, 2, \ldots n$ represent a random sample from a bivariate distribution, was satisfied through the research design. The respondent's estimates, Y_i, were randomly drawn from a distribution of all possible estimated values for activity A_i. The value of X_i, on the other hand, was obtained by actual

measurement of activity A_i. The fourth assumption, the measurement scale for the X's and Y's was at least interval, was satisfied in that the values associated with the X's and Y's were ratio level data. An absolute zero or origin was identifiable and such statements as "less than", "equal to", and "greater than" could have been made in measurable terms.

CRITERIA FOR RESOLVING DIVERGENT INDICES

It was likely that some personnel might have estimated the force, time, and/or distance variables with non-representative values, either because they failed to comprehend the estimation tasking or possibly because they provided estimates of the variables simply to satisfy the requirement without regard for data quality. In instances where divergent index estimates for an activity were suggested by sample data values not being clustered about their sample means (computed including these values), the following decision rule was applied to determine when to exclude these extreme values from the sample data:

> Any values that exceed $\pm$ 3 standard deviations were excluded from the set of sample data and the sample size decreased accordingly.

In applying this decision rule, the sample mean ($\overline{X}$) and standard deviation(s) of index estimates of a variable for an activity were computed, and raw data values exceeding

$\pm$ 3 sample standard deviations about the mean were removed from the data base. The sample mean ($\overline{X}$) and standard deviation were then recomputed on the reduced set of sample index estimates.

Estimated index values that were not representative could have easily influenced the sample mean and, accordingly, the normalized difference for the activity (18:74). If such values were not excluded, the normalized difference would have been an unacceptable test statistic because it was sensitive to (or reflected) the actual differences between the estimated indices and the standard for a particular activity and their distribution through the standard deviation estimated from the sample data. Consequently, the application of this decision rule excluded outrider values from the sample data set so that computed normalized difference values for an activity were more representative of behavior of index estimates associated with the activity (17). Where this decision rule was invoked, the index, sample mean, and standard deviation were computed with those values which exceeded $\pm$ 3 standard deviations, and also computed without those values. The Wilcoxon Signed Rank Test was accomplished for both sets of data values and the results compared to determine what effect inclusion, versus exclusion, had on the Wilcoxon test.

LIMITATIONS

The major limitations of this research effort centered around the time involved to conduct individual interviews and the time available to the researchers.

ASSUMPTIONS

The assumptions under which this research was conducted were as follows:

1. The personnel assigned to the pilot test were representative of the population.

2. The terms and quantitative measures used were adequately defined and understood.

3. The full cooperation of the personnel interviewed was obtained to provide their best estimates of physical demands for the tasks evaluated.

Chapter 4

ANALYSIS OF RESULTS

This chapter contains the analysis of the data collected in this study. The first section of the chapter presents a discussion of the data obtained, and how the data satisfied the necessary assumptions of the Wilcoxon Signed Rank test. The second section provides the analysis of the data by individual task and by all three tasks combined, and the results of those statistical tests. The third section provides a summary of the conclusions drawn by the researchers.

DATA REQUIREMENTS FOR THE WILCOXON SIGNED RANK TEST

The first assumption requires that each D_i must be a continuous random variable. The data satisfied this assumption since the values of X_i and Y_i used in computing D_i assumed real number values dependent upon the standard (X_i) and the respondents estimates (Y_i) of force, time and distance variables. Both the standard (determined by work sampling) and the individual estimates of the three variables, force, time, and distance, were unrestricted, continuous, ratio level data which provided the base for computing the value of D_i. The second assumption required

that the distribution of each D_i by symmetric; that is, the probability that D_i was positive was equal to the probability that D_i was negative for any D_i. Figures 4 through 6 represent frequency plots of the D_i values obtained for each of the three removal and replacement tasks, described in Chapter 3, and Figure 7 is a plot of the D_i values for all three tasks combined. The sample distributions exhibit the following parameters as shown in Table 2.

Table 2

Sample Data Distribution by Task

	RT 220	Search Radar Antenna	RT 289	All Three Tasks Combined
Mean	0.53037	0.32299	0.01269	0.20585
Variance	1.30997	0.93149	1.40063	1.31857
Standard Deviation	1.14454	0.96514	1.18348	1.14829
Relative Skewness(β_1)	0.72858	1.170516	0.43482	0.54363

For a distribution to be perfectly symmetrical, the value for β_1 would be equal to zero. The larger the value of β_1 the greater the degree of relative skewness. The values of β_1 indicate that each of the sample distributions were skewed to the right. Since each of these distributions was based on a sample of sixteen respondents, it would not be unrealistic to assume that these distributions would be symmetric if the sample size was increased. Consequently, the researchers believed that the distributions

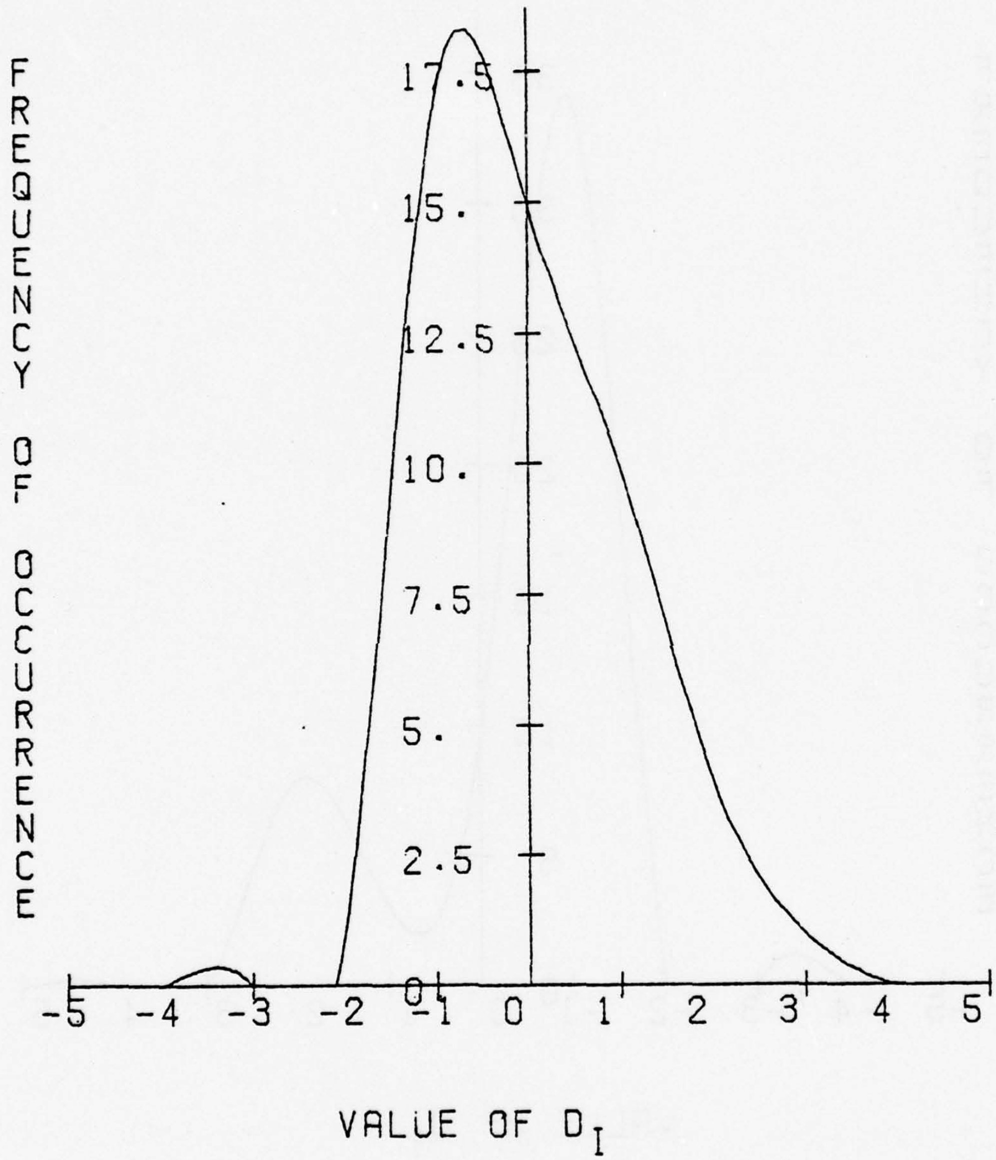


Figure 4

Distribution of D_i -- RT 220

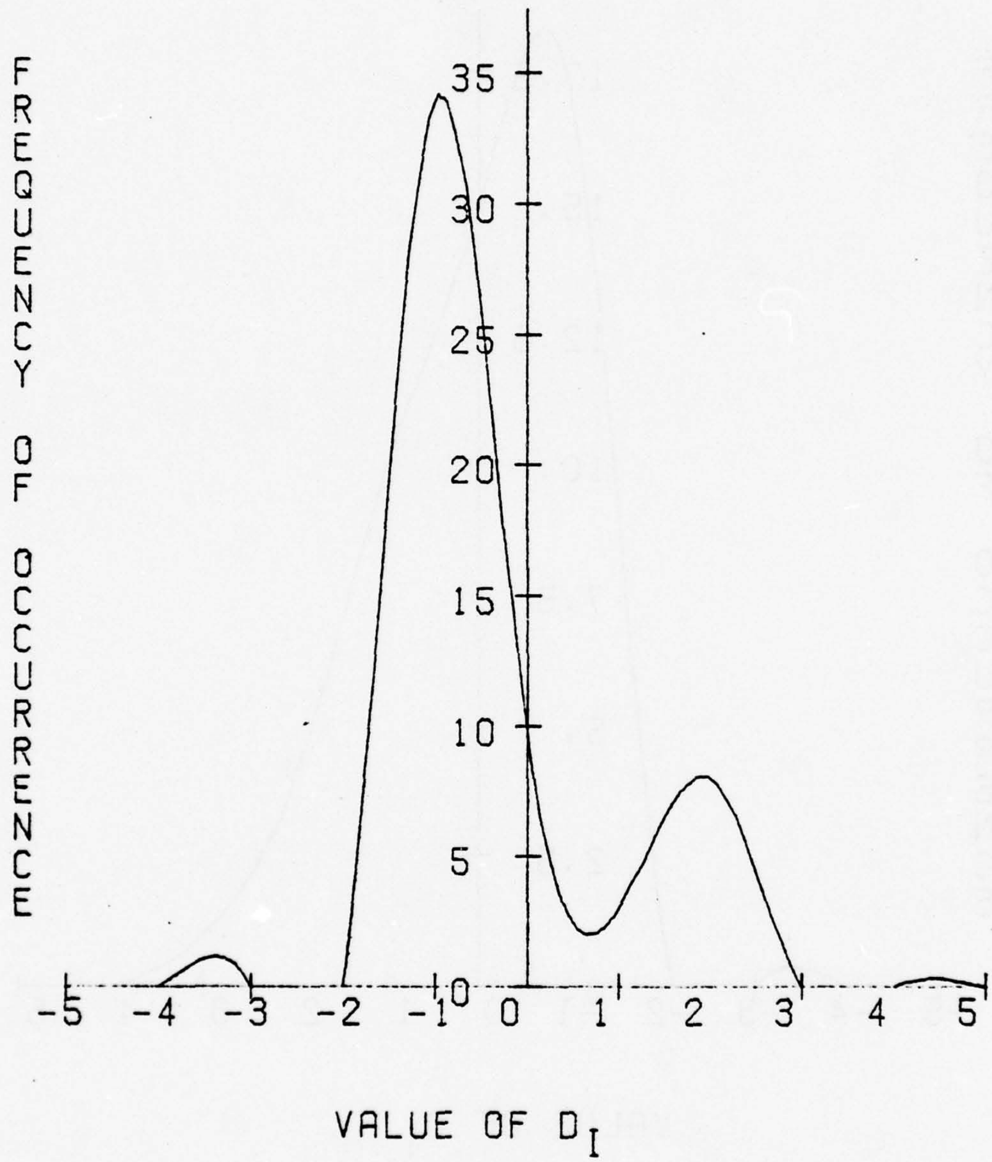


Figure 5

Distribution of D_i -- Search Radar Antenna

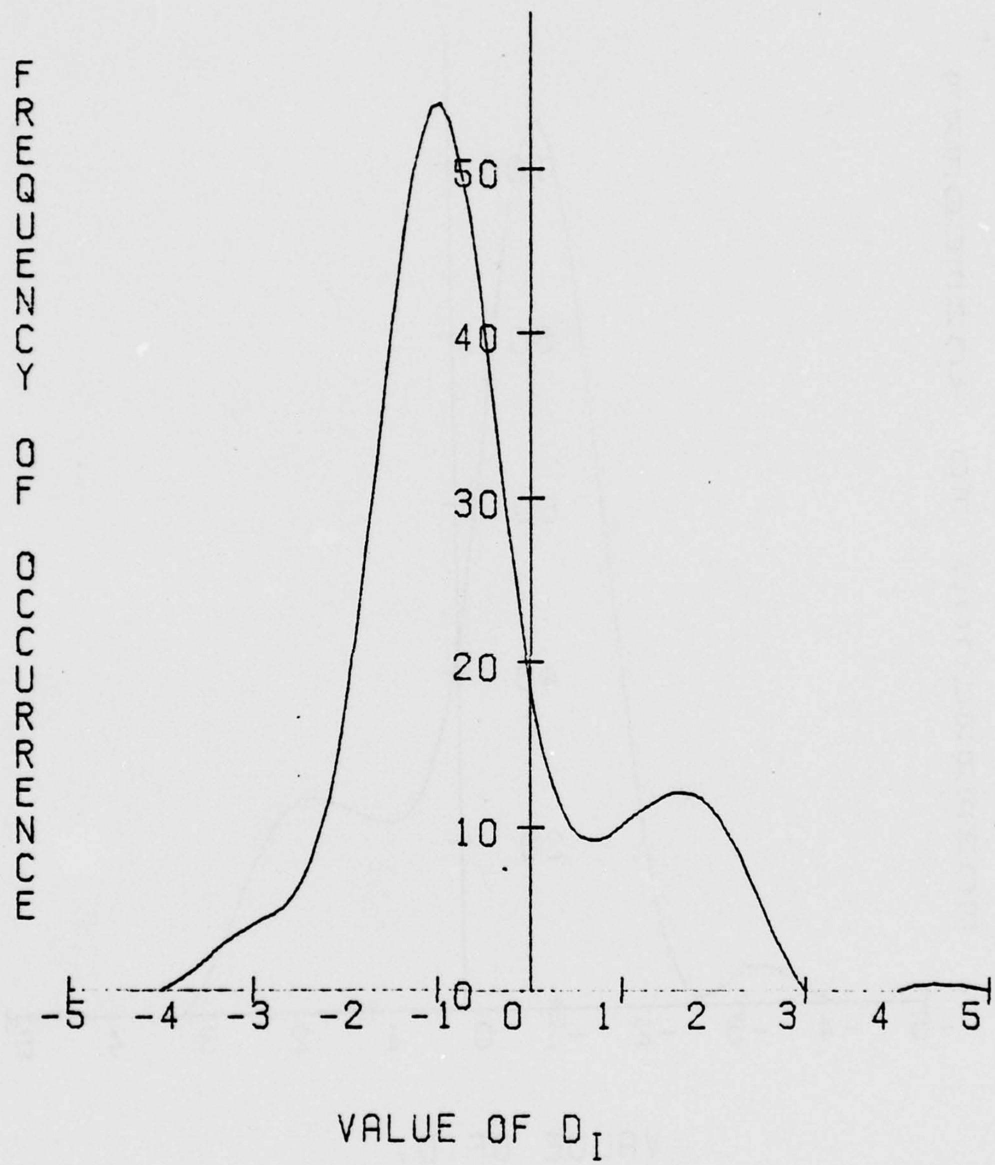


Figure 6

Distribution of D_i -- RT 289

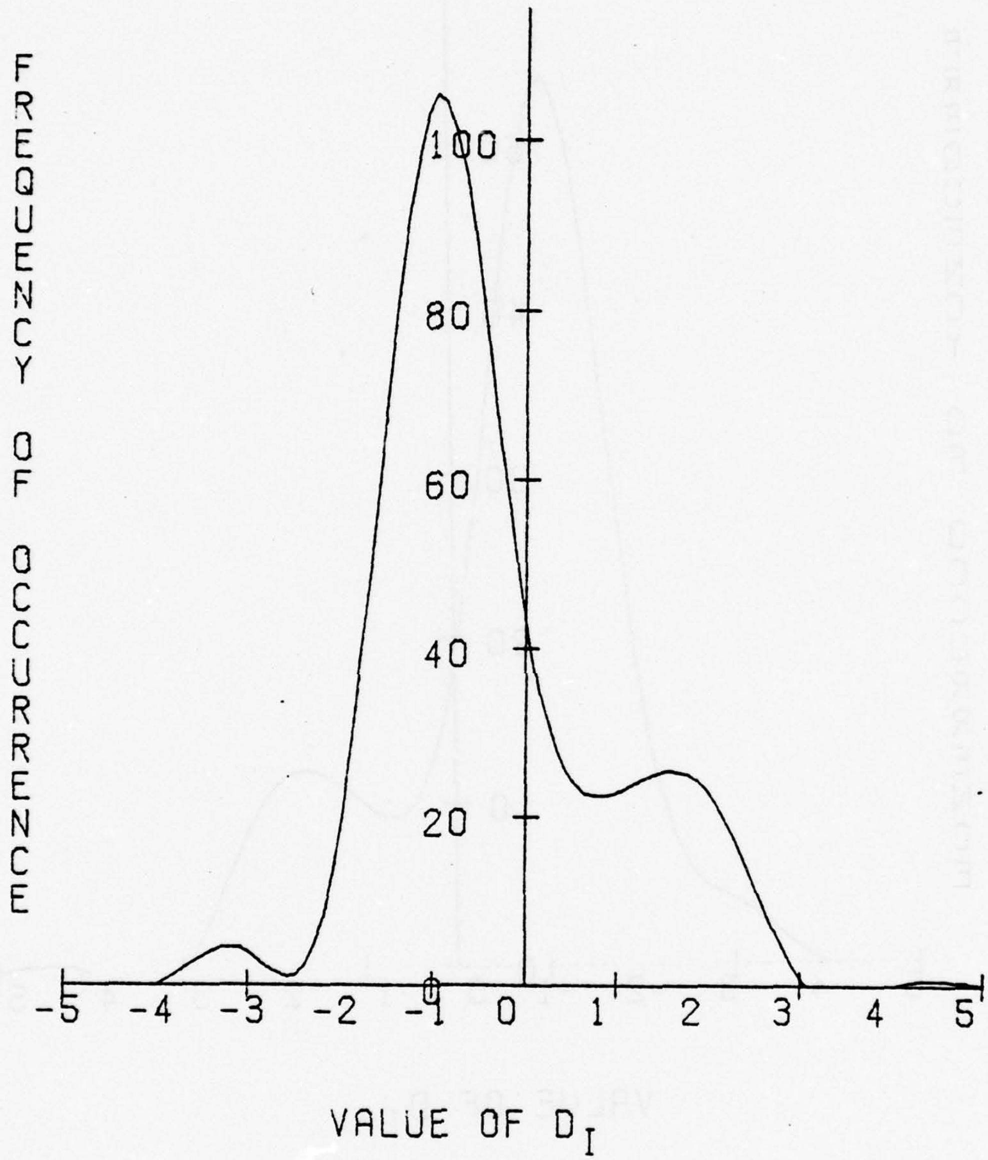


Figure 7

Distribution of D_i -- All Tasks

evidenced sufficient symmetry to satisfy the second assumption of the Wilcoxon test (17).

The third assumption, that the pairs (X_i, Y_i), $i = 1, 2, \ldots n$ represent a random sample from a bivariate distribution, appeared to be satisfied. The estimates (Y_i) for each activity provided by the sixteen respondents represent a random sample from a bivariate distribution. Each respondent individually evaluated the task and provided estimates of force, time, and distance for a total of 23 procedural steps, i.e. activities, identified in the removal and replacement procedures of the equipment where the activity required the application of forces of ten pounds or greater. For the purposes of this basic research, it was assumed that the respondent's estimates for each activity also represent a random sample from a bivariate distribution.

The fourth assumption required that the measurement scale for the standard (X_i's) and the respondent (Y_i's) estimates was at least interval level data. This assumption was satisfied since the values associated with the X's and Y's have an identifiable origin or absolute zero, and statements as "less than", "equal to", and "greater than" could be made in measurable terms. The data obtained for the X's and Y's was, in fact, ratio level data.

REMOVAL AND REPLACEMENT OF RECEIVER-TRANSMITTER RT 220/ARN21 - TACAN

The technical order removal and replacement procedures are provided in Appendix C, paragraphs 11-55 and 11-56 respectively, of Technical Order 1C-135A-2-11-1 (21). The following information and data was obtained in evaluating the removal and replacement steps.

Receiver-Transmitter -- Removal (11-55)

Step a--Loosen the hold-down clamps. This step entailed loosening the hold-down clamps securing the receiver-transmitter to the mount. Removal of the hold-down clamps required the hand loosening of two wing nuts until the securing assemblies could be positioned out of the removal path of the receiver-transmitter. Personnel estimated the force they applied to the wing nuts and the time during which the force was applied. Eight respondents identified the activity as being non-significant, i.e. requiring the application of a force of less than ten pounds, while eight respondents estimated the force application in excess of ten pounds as shown in Table 3.

Step b--Remove unit from mount. The removal of the unit required grasping a lifting handle and pulling the unit towards the technician until the unit separated from the rear-mounted bayonet-type electrical connector. The

Table 3

RT 220, Step a of Remove

	Force (lb)	Time (sec)	Index* (lb/sec)
Mean:	22.500	7.125	3.448
Standard Deviation:	13.887	3.871	2.126
Standard per Clamp:	3.75	5.0	0.075

* 8 respondent estimates

unit was pulled horizontally from its mounting position, rotated 90 degrees and placed in an area adjacent to the work location. The standard, determined by work sampling, showed that fifty pounds of force was exerted for a period of 15 seconds to achieve removal of the unit from its mount and to position it out of the work area. A summary of the respondent estimates is shown in Table 4.

Table 4

RT 220, Step b of Remove

	Force (lb)	Distance (ft)	Time (sec)	Index* (ft-lb/sec)
Mean:	47.938	6.875	23.621	27.129
Standard Deviation:	12.086	3.832	29.980	24.820
Standard:	50.0	7.0	15.0	23.333

* 16 respondent estimates

Receiver-Transmitter --
Installation (11-56)

Step a--Position receiver-transmitter in mount. This step involved positioning the receiver-transmitter in the mount and checking that the electrical connector mated properly. The installation of the receiver-transmitter RT 220 was the reverse of the removal actions. A summary of the respondent estimates in shown in Table 5.

Table 5

RT 220, Step a of Replace

	Force (lb)	Distance (ft)	Time (sec)	Index* (ft-lb/sec)
Mean:	47.750	6.250	25.875	19.488
Standard Deviation:	12.482	3.061	28.556	16.292
Standard:	50.0	7.0	18.0	19.444

* 16 respondent estimates

Step b--Engage, tighten, and lockwire hold-down clamps. The engaging and tightening of the hold-down clamps was the reverse of the removal procedure. Eight respondents identified the task as being non-significant while eight respondents identified the task as requiring the application of forces in excess of ten pounds as shown in Table 6.

Table 6

RT 220, Step b of Replace

	Force (lb)	Time (sec)	Index* (lb/sec)
Mean:	28.125	6.875	4.922
Standard Deviation:	16.022	4.051	3.345
Standard per Clamp:	3.75	6	.625

* 8 respondent estimates

Test of Hypothesis

The first test of hypothesis was performed using all data values obtained for each of the removal and replacement activities for the RT 220. The value of D_i was computed for each respondent's estimate and the Wilcoxon two-tail test was performed. The results of the test are shown in Table 7. An example computation and ranking of D_i, and computation of the statistics R^-, R^+, and W_α critical limits are shown in Appendix E.

The results show that the researchers had to reject H_0, accept H_1, and conclude that the information provided from the individual estimates was statistically not the same information as that obtained through actual measurement.

In evaluating where the respondent's estimates varied significantly from the data obtained from work measurement, it was found that the respondents overestimated the forces required to loosen and tighten the hold-down

Table 7

RT 220, Hypothesis Test

Number D_i values	48
Sum of R^+ ranks	849
Sum of R^- ranks	327
R statistic	327
Lower critical limit: $W_{0.025}$	369.9
Upper critical limit: $W_{0.975}$	779.9

Hypothesis: H_0: $\mu_x = \mu_y$

H_1: $\mu_x \neq \mu_y$

$$W_{0.025} < R$$

$$369.9 \not< 327$$

Decision Rule: Reject H_0 if at the $\alpha = 0.05$ significance level R exceeds $W_{0.975}$, or R is less than $W_{0.025}$, otherwise accept H_0.

Reject H_0, Accept H_1

clamps securing the receiver-transmitter to its mount. As previously indicated, the loosening and tightening of the hold-down clamp wing nut was accomplished by hand. The location and position of the wing nuts made them extremely difficult to reach. The wing nuts were located underneath the front of the receiver and slightly above the floor of the aircraft. Access to the wing nuts was hindered by a one and one-half inch metal lip which the technicians had to work over to reach the wing nuts because the fixed aircraft structures would not permit side access to the hold-down clamp wing nuts. Consequently, the loosening and tightening of the two wing nuts was accomplished by the technician using the first fingers of both hands while essentially crouched on knees and elbows.

The Wilcoxon test was performed again with the data values for the loosening and tightening of the hold-down clamps removed. The results of the test are shown in Table 8. Based on the statistical test, the researchers could not reject H_0 and concluded that the information obtained from the respondents could not be shown to be other than the same information obtained through measurement.

The researchers concluded that the respondent's estimates of the forces they perceived as having to exert in order to accomplish the required maintenance actions were apparently influenced by the awkward body position required to gain access to the hold-down clamp wing nuts.

Table 8

RT 220, Hypothesis Test - Steps Removed

Number D_i values	32
Sum of R^+ ranks	248
Sum of R^- ranks	280
R statistic	248
Lower critical limit: $W_{0.025}$	159.2
Upper critical limit: $W_{0.975}$	368.8

Hypothesis: H_0: $\mu_x = \mu_y$

H_1: $\mu_x \neq \mu_y$

$$W_{0.025} < R < W_{0.975}$$

$$159.2 < 248 < 368.8$$

Fail to Reject H_0

The forces they perceived as having to exert were 500 percent greater than the forces actually required to loosen the hold-down clamp, and 650 percent greater than the forces actually required to tighten the hold-down clamp.

REMOVAL AND REPLACEMENT OF SEARCH RADAR ANTENNA

The technical order removal and replacement procedures are provided in Appendix C, paragraphs 16-106 and 16-107 respectively of Technical Order 1C-135A-2-11-1 (21).

Search Radar Antenna -- Removal (16-106)

Steps a through c constituted removal of the aircraft nose radome to provide access to the search radar antenna. In this organization these tasks were normally accomplished by the aircraft crew chief. The respondents in the pilot test AFSC did not perform radome removal. Consequently, these steps were not evaluated in this study.

Step d--Disconnect waveguide from antenna. This step involved the removal of the four mounting screws connecting the waveguide to the top of the antenna. Disconnecting the waveguide required loosening and removing four machine screws using a standard screwdriver, and positioning the waveguide out of the way of antenna removal. Fifteen of the sixteen respondents identified the task as being non-significant. Subsequent measurement of the force

required to remove the machine screws was one pound of force for a duration of one second, indicating that the activity was indeed judged accurately by 94 percent of the respondents as being non-significant.

Step e--Disconnect the electrical connectors. Removal of electrical connectors required cutting and discarding the safety wire securing each electrical connector. Each electrical connector was subsequently removed by loosening a knurled retainer ring, and then alternately unscrewing the knurled retainer ring and pulling the male portion of the connector from its mating connector on the radar unit until the male portion was disconnected. As each electrical connector was removed, it was positioned out of the way to permit radar unit removal.

Of the sixteen respondents evaluating the task, nine identified the tasks as requiring the application of significant force, while seven respondents estimated forces less than ten pounds. A summary of respondent estimates is shown in Table 9.

Table 9

Antenna, Step e of Remove

	Force (lb)	Distance (ft)	Time (sec)	Index* (ft-lb/sec)
Mean:	22.500	.062	35.833	0.059
Standard Deviation:	10.368	.027	15.303	0.053
Standard per Connector:	26.0	.0415	24	0.045

* 9 respondent estimates

__Step f--Remove center bolt from shockmount.__ Removal of each centerbolt and lockwasher from each of three shockmounts required the cutting and discarding of safety wires securing the bolt. Each centerbolt was removed from the shockmount using a 7/16 inch socket and 3/8 inch drive ratchet.

Of the sixteen respondents evaluating the task, eleven identified the task as requiring non-significant application of forces, whereas five respondents estimated required forces greater than ten pounds. The respondent estimates are summarized in Table 10.

Table 10

Antenna, Step f of Remove

	Force (lb)	Time (sec)	Index* (lb/sec)
Mean:	23.0	5.0	7.200
Standard Deviation:	9.747	3.240	7.190
Standard per Bolt:	15.0	3.0	5.0

* 5 respondent estimates

The technical order procedures did not provide a step requiring the removal of the antenna. Normally, such a step would follow the CAUTION after Step f. The technical order assumed the technician would, after reading the CAUTION, accomplish radar unit removal in accordance with the CAUTION. To insure respondents would provide estimates

for removing the antenna, the following step was included on the interview worksheet.

Step g--Remove antenna from aircraft. Antenna removal required lifting the antenna vertically above its mount, moving it horizontally away from its mount, and inverting the antenna. The antenna was then lowered until it came to rest on a maintenance stand. The respondent estimates are summarized in Table 11.

Table 11

Antenna, Step g of Remove

	Force (lb)	Distance (ft)	Time (sec)	Index* (ft-lb/sec)
Mean:	51.81	8.69	35.63	18.39
Standard Deviation:	7.86	3.80	16.97	16.35
Standard:	55	8.17	28.0	16.04

* *16 respondent estimates*

Search Radar Antenna --
Installation (16-107)

Installation of the antenna involved raising the antenna into position, securing it to the airframe, and connecting the electrical connectors and waveguide.

Step a--Put antenna in place. This step entailed positioning the radar antenna on its mounting brackets, and was accomplished in the reverse of the removal actions.

The respondent estimates are summarized in Table 12.

Table 12

Antenna, Step a of Replace

	Force (lb)	Distance (ft)	Time (sec)	Index* (ft-lb/sec)
Mean:	52.13	8.44	44.19	18.90
Standard Deviation:	8.10	3.70	25.31	21.58
Standard:	55	8.17	43.0	10.46

* 16 respondent estimates

Step b--Install centerbolt in shockmount. The installation of the centerbolt and lockwasher in each of three shockmounts was accomplished using the reverse of the removal actions. Of the sixteen respondents, ten identified the task as non-significant, while six respondents identified the task as requiring the application of forces of ten pounds or greater. The respondent estimates are summarized in Table 13.

Table 13

Antenna, Step b of Replace

	Force (lb)	Time (sec)	Index* (lb/sec)
Mean:	17.50	2.58	8.86
Standard Deviation:	2.74	1.43	5.84
Standard per Bolt:	15.0	3.0	5.0

* 6 respondent estimates

Step c--Connect the electrical connectors. Electrical connectors were connected using the reverse of the removal actions. Nine of the respondents identified the task as non-significant while seven identified the task as requiring the application of forces of ten pounds or greater. The respondent estimates are summarized in Table 14.

Table 14

Antenna, Step c of Replace

	Force (lb)	Distance (ft)	Time (sec)	Index* (ft-lb/sec)
Mean:	22.14	.065	32.57	0.059
Standard Deviation:	9.51	.026	16.57	0.053
Standard per Connector:	26.0	.0415	24.0	0.045

* 7 respondent estimates

Step d--Connect the waveguide to antenna. Connecting the waveguide to the top of the antenna by installing four mounting screws was accomplished using the reverse of the disconnecting actions. The activity was considered non-significant by fifteen of the sixteen respondents. For that reason the single respondent data value for this step was not included in the sample data.

Steps e through i constituted positioning and installing the aircraft nose radome. The respondents in the pilot test AFSC did not perform radome installation. Consequently these steps were not evaluated in this study.

Test of Hypothesis

The test of hypothesis was performed using all data values for each activity identified as significant in the removal and replacement procedures for the search radar antenna. The value of D_i was computed for each respondent's estimate and the Wilcoxon two-tail test performed. The results of the test are shown in Table 15.

The statistical test indicated that the researchers could not reject H_0 and therefore concluded that the information obtained from the respondents could not be shown to be other than the same information obtained through measurement.

REMOVAL AND REPLACEMENT OF SEARCH RADAR RECEIVER-TRANSMITTER RT 289/APN59

The technical order removal and replacement procedures are provided in Appendix C, paragraphs 16-90 and 16-91 respectively of Technical Order 1C-135A-2-11-1 (21).

Search Radar Receiver-Transmitter -- Removal (16-90)

The WARNING prior to Step a required personnel to position support equipment such as the B-4 or equivalent maintenance stand. Respondents were asked to evaluate positioning of the B-4 maintenance stand. The summarized respondent estimates are shown in Table 16.

The B-4 maintenance stand is a general purpose stand used in aircraft maintenance. Stand height adjustment

Table 15

Search Radar Antenna, Hypothesis Test

Number of D_i values	55
Sum of R^+ ranks	855
Sum of R^- ranks	685
R statistic	685
Lower critical limit: $W_{0.025}$	536.07
Upper critical limit: $W_{0.975}$	1003.93

Hypothesis: H_0: $\mu_x = \mu_y$

H_1: $\mu_x \neq \mu_y$

$$W_{0.025} < R < W_{0.975}$$

$$536.07 < 685 < 1003.93$$

Fail to Reject H_0

was accomplished by operating a single action hydraulic hand pump. Positioning the stand was accomplished by pushing/pulling the stand into the desired position. Two personnel identified positioning of the B-4 stand as requiring the application of forces less than ten pounds.

Table 16

RT 289, B-4 Stand Positioning

	Force (lb)	Distance (ft)	Time (sec)	Index* (ft-lb/sec)
Mean:	41.07	18.21	104.64	13.676
Standard Deviation:	18.21	8.23	98.17	12.458
Standard:	24.0	22.5	100.0	5.4

* 14 respondent estimates

<u>Step a--Turn off radar pressurization</u>. *This step* involved turning off the radar pressurizing system by placing the system power switch on the radar pressurizing control panel on the navigator's radar control console to the "OFF" position. All sixteen respondents rated the task as non-significant. Evaluation of the task indicated that the task required the application of forces less than ten pounds and was correctly evaluated by the respondents.

<u>Step b_1--Disconnect pressurization line</u>. Step b was divided into two separate steps to insure the respondents would provide separate and independent estimates for each activity.

Disconnecting the unit pressurization line required loosening a B-nut located on the side of the receiver-transmitter and unscrewing the nut by hand until completely removed. Once loosened, forces less than ten pounds were required to unscrew the B-nut. Eleven respondents rated the task as non-significant, while five respondents identified the forces required as ten pounds or greater. The respondent estimates are summarized in Table 17.

Table 17

RT 289, Step b_1 of Remove

	Force (lb)	Time (sec)	Index* (lb/sec)
Mean:	17.40	2.60	8.03
Standard Deviation:	3.72	1.52	3.08
Standard:	14.0	3.0	4.67

* 5 respondent estimates

Step b_2--Disconnect waveguide from receiver-transmitter. Disconnecting the waveguide from the receiver-transmitter required the loosening and removal of four machine screws using a common screwdriver. Fifteen of the sixteen respondents rated the task as requiring application of forces less than ten pounds. The standard, developed by work sampling, indicated that three pounds of force was required to loosen each screw which turned freely after loosening.

AD-A047 663 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OHIO SCHO--ETC F/G 5/9
A STUDY TO QUANTIFY THE PHYSICAL DEMANDS PLACED UPON PERSONNEL --ETC(U)
SEP 77 F P ARBEIT, H A SCHEAFER

UNCLASSIFIED AFIT-LSSR-37-77B NL

2 OF 2
ADI
A047663

END
DATE
FILMED
1 -78
DDC

Step c--Disconnect electrical connectors. Three cannon plug type electrical connectors were removed from the receiver-transmitter by alternately unscrewing a knurled retainer ring and pulling on the male portion of the electrical connector until completely disconnected from the receiver-transmitter. Eight of the sixteen respondents identified the task as requiring forces less than ten pounds, whereas eight respondents identified forces of ten pounds or greater. The respondent estimates are summarized in Table 18.

Table 18

RT 289, Step c of Remove

	Force (lb)	Distance (ft)	Time (sec)	Index* (ft-lb/sec)
Mean:	22.50	0.065	30.71	0.060
Standard Deviation:	9.64	0.024	10.97	1.048
Standard:	26.0	0.0415	24.0	.04496

* 8 respondent estimates

Step d_1--Disconnect ground straps from mounting ring. Step d was divided into two separate steps to insure respondents would provide separate and independent estimates for each activity.

Disconnecting the ground straps required the removal of a phillips-head machine screw. Fourteen of the sixteen respondents identified the task as requiring forces less than ten pounds. The standard showed that three

pounds of force was required to loosen the screw. This step was not included in the sample data since approximately ninety percent of the respondents identified the task as being non-significant.

Step d_2--Remove mount bolts securing receiver-transmitter. The removal of the three mount bolts and associated hardware from the receiver-transmitter mount brackets required the loosening and unscrewing of three allen head cap screws. Ten respondents indicated that the task required the exertion of forces of less than ten pounds. The estimates of the six respondents who rated it as significant are summarized in Table 19.

Table 19

RT 289, Step d_2 of Remove

	Force (lb)	Time (sec)	Index* (lb/sec)
Mean:	23.33	3.12	8.75
Standard Deviation:	9.83	1.47	5.89
Standard per Bolt:	24.0	4.0	8.00

* 6 respondent estimates

Step e_1--Lift receiver-transmitter from mounting ring. Step e was divided into two separate steps to insure respondents would provide separate and independent estimates for each activity.

Removal of the receiver-transmitter from its mount involved lifting the unit from the mounting ring so as not to cause damage to the receiver-transmitter or surrounding equipment and moving it horizontally over the entrance hatch. The receiver-transmitter was then lowered to a temporary area adjacent to the hatch sill for subsequent removal. The respondent estimates are summarized in Table 20.

Table 20

RT 289, Step e_1 of Remove

	Force (lb)	Distance (ft)	Time (sec)	Index* (ft-lb/sec)
Mean:	79.56	2.74	20.25	18.85
Standard Deviation:	10.12	1.85	22.80	19.48
Standard:	88.0	3.67	19.0	16.98

* 16 respondent estimates

<u>Step e_2--Remove receiver-transmitter from lower nose compartment</u>. The removal of the receiver-transmitter was accomplished by lifting it from its temporary resting area, moving it horizontally until free from surrounding obstructions and lowering it through the nose hatch until it came to rest on the maintenance stand. The respondent estimates are summarized in Table 21.

Table 21

RT 289, Step e_2 of Remove

	Force (lb)	Distance (ft)	Time (sec)	Index* (ft-lb/sec)
Mean:	78.13	6.88	28.38	42.27
Standard Deviation:	8.34	2.85	20.33	51.97
Standard:	88.0	7.0	8.0	

* 16 respondent estimates

Search Radar Receiver-Transmitter -- Installation (16-91)

Step a_1--Insert receiver-transmitter into nose compartment. Step a was divided into two steps to insure respondents would provide separate and independent estimates for each activity.

This step involved carefully inserting the receiver-transmitter into the nose compartment. The receiver-transmitter was lifted from the maintenance stand and positioned adjacent to the mounting ring where it was temporarily placed prior to installation in the mounting ring. The respondent estimates are summarized in Table 22.

Table 22

RT 289, Step a_1 of Replace

	Force (lb)	Distance (ft)	Time (sec)	Index* (ft-lb/sec)
Mean:	78.63	4.56	18.5	26.92
Standard Deviation:	8.69	2.15	10.68	21.33
Standard:	88.0	7	12	51.33

* 16 respondent estimates

Step a_2--Install receiver-transmitter into mounting ring. This step entailed installing the receiver-transmitter into the mounting ring with the three mount brackets coming to rest on the shock mounts. The receiver-transmitter was lifted from its temporary resting place, positioned over the mounting ring and lowered onto its shock mounts. Table 23 provides a summary of the respondent estimates for this step.

Table 23

RT 289, Step a_2 of Replace

	Force (lb)	Distance (ft)	Time (sec)	Index* (ft-lb/sec)
Mean:	79.56	2.41	21.31	17.36
Standard Deviation:	10.12	1.42	21.29	19.15
Standard:	88.0	2.0	13.0	13.54

* 16 respondent estimates

Step b_1--Install three mount bolts. This step involved the installation of three mount bolts and hardware in the three mounting brackets on the receiver-transmitter. The installation and tightening of the bolts was the reverse of the removal actions. The respondent estimates are summarized in Table 24.

Step b_2--Connect ground straps. This step involved connecting the three ground straps to the mounting ring. The installation of the ground straps was accomplished using

Table 24

RT 289, Step b_1 of Replace

	Force (lb)	Time (sec)	Index* (lb/sec)
Mean:	18.75	4.75	5.06
Standard Deviation:	2.50	2.50	3.35
Standard per Bolt:	24.0	4.0	8.0

* 4 respondent estimates

the reverse of the removal actions. Fifteen of the sixteen respondents identified the task as requiring the application of less than ten pounds force, i.e. non-significant. The standard indicated that three pounds of force was required for a duration of two seconds to tighten the machine screws. Since 94 percent of the respondents identified the task as non-significant, the single estimate was not included in the sample data.

<u>Step c--Connect the electrical connectors</u>. The connection of the electrical connectors was accomplished using the reverse of the removal actions. Eight of the sixteen respondents identified the task as requiring ten pounds or greater force. Their estimates are summarized in Table 25.

<u>Step d--Connect waveguide</u>. This step involved the connection of the waveguide to the receiver-transmitter by installing the four mounting screws. Fourteen of the sixteen respondents identified the task as requiring the

Table 25

RT 289, Step c of Replace

	Force (lb)	Distance (ft)	Time (sec)	Index* (ft-lb/sec)
Mean:	23.13	.056	24.00	.121
Standard Deviation:	9.23	.021	11.93	.205
Standard per Connector:	26.0	.0415	24.0	.045

* 8 respondent estimates

application of forces less than ten pounds. Three pounds of force was required to tighten each machine screw. Therefore, the step was considered non-significant and not included in the sample data.

Step e--Connect pressurization line. Reconnecting the receiver-transmitter pressurization line was accomplished using the reverse of the disconnecting actions. Six of the sixteen respondents identified the task as requiring the application of forces ten pounds or greater. Their estimates are summarized in Table 26.

Table 26

RT 289, Step e of Replace

	Force (lb)	Time (sec)	Index* (lb/sec)
Mean:	23.33	3.17	7.65
Standard Deviation:	9.83	1.17	2.34
Standard:	14.0	3.0	4.67

* 6 respondent estimates

Test of Hypothesis

The test of hypothesis was performed using all data values obtained for each activity judged significant in the removal and replacement procedure for the RT 289 Receiver-Transmitter. The value of D_i was computed for each of the respondent's estimates and the Wilcoxon two-tail test performed. The results are shown in Table 27. The test showed that the researchers could not reject H_0 and therefore concluded that the information obtained from the respondents could not be shown to be other than the same information obtained through actual measurement.

ADDITIONAL TESTS ON DATA

In addition to conducting hypothesis tests by individual tasks, a test of hypothesis was conducted for all three tasks combined to determine if the results would equal those of the tasks tested individually. The results shown in Table 28 were obtained when all D_i values were combined and the Wilcoxon test performed.

The statistical test showed that the researchers could not reject H_0 and concluded that the information obtained from the respondents could not be shown to be other than the same information obtained through actual measurement. This test of the hypothesis included the D_i values for the two steps which caused the rejection of the null hypothesis for the remove and replace RT 220 task.

Table 27

RT 289, Hypothesis Test

Number of D_i values	114
Sum of R^+ ranks	2875.5
Sum of R^- ranks	3679.5
R statistic	2875.5
Lower critical limit: $W_{0.025}$	2584.3
Upper critical limit: $W_{0.975}$	3970.7

Hypothesis: H_0: $\mu_x = \mu_y$

H_1: $\mu_x \neq \mu_y$

$$W_{0.025} < R < W_{0.975}$$

$$2584.3 < 2875.5 < 3970.7$$

Fail to Reject H_0

Table 28

Hypothesis Test Data --
All Steps, All Tasks

Number of D_i values	217
Sum of R^+ ranks	12573.5
Sum of R^- ranks	11079.5
R statistic	11079.5
Lower critical limit: $W_{0.025}$	10011.6
Upper critical limit: $W_{0.975}$	13641.4

Hypothesis: H_0: $\mu_x = \mu_y$

H_1: $\mu_x \neq \mu_y$

$$W_{0.025} < R < W_{0.975}$$

$$10011.6 < 11079.5 < 13641.4$$

Fail to Reject H_0

To determine what effect the removal of the steps requiring the loosening and tightening of the hold-down clamp wing nut which caused the rejection of the null hypothesis in the removal and replacement of the RT 220 task would have when all three tasks were combined, a second Wilcoxon test was performed with those data values removed. The results of this test are shown in Table 29. With those two steps removed, the test still did not reject H_0. The researchers again concluded that the information obtained from the respondents could not be shown to be other than the same information obtained through actual measurement. In both of the above tests, the null hypothesis could not be rejected.

OTHER FINDINGS

The use of technical order procedures and the AFSC's Specialty Training Standard as the source documents for development of the interview/observation instrument presented some potential problems. For example, the procedures identified for the removal and replacement of the search radar antenna required the removal and subsequent replacement of the aircraft nose radome, a task which was normally performed by 43XXX AFSC personnel. The problem presented itself in that the technical order procedures did not identify which AFSC performs what actions when task accomplishment requires the coordinated effort of two or

Table 29

Hypothesis Test Data --
Two Steps Removed,
All Tasks

Number of D_i values	201
Sum of R^+ ranks	9685.5
Sum of R^- ranks	10615.5
R statistic	9685.5
Lower critical limit: $W_{0.025}$	8532.1
Upper critical limit: $W_{0.975}$	11768.9

Hypothesis: H_0: $\mu_x = \mu_y$

H_1: $\mu_x \neq \mu_y$

$$W_{0.025} < R < W_{0.975}$$

$$8532.1 < 9685.5 < 11768.9$$

Fail to Reject H_0

more AFSCs. In addition, further complications could occur in the development of an appropriate interview/ observation worksheet because personnel in a given AFSC may be trained to perform maintenance actions outside of their AFS as identified in the AFSC's basic Specialty Training Standard (5:6-1,6-7). Such additional requirements could be generated at the workcenter level and would be peculiar to the situation within the work center(s) involved. Consequently, at some Air Force installations, AFSC 32XXX may be tasked to perform radome removal and replacement, while at other installations, such as Wright-Patterson AFB, AFSC 32XXX would not perform radome removal and replacement.

The use of technical order procedures also presented two other potential problems. First, the technical order procedures did not in all cases identify all the actions required to be accomplished. The absence of a procedural step to "remove" the search radar antenna is one such example. The procedure "assumes" the technician would "remove" the antenna in accordance with the CAUTION following step 16-106f. Second, technical order procedures often included two or more separate actions in one step. This was evident in the removal and replacement procedure for both the search radar antenna and receiver-transmitter RT 289.

In analyzing the data obtained from the three tasks evaluated, one other factor was observed which warrants

comment. The size and perceived mass of an object appeared to influence the respondent's estimates of the forces involved to move it. This factor resulted in the respondent's quantitative estimates being consistently larger than that actually measured. The B-4 maintenance stand is relatively large, constructed of heavy steel tubing, and rolls on four large hard rubber swivel castors. The range of the respondent's estimates of the force required to position the maintenance stand was from 20 to 70 pounds with a mean value of 41.07 pounds. The standard measured for maneuvering the stand represents the average value for positioning the stand under the differing surface conditions found on the flight line and in an aircraft hanger. The respondent's estimates were 71 percent greater than the force required to actually maneuver the stand. Based on the respondent's estimates, it appeared as though personnel tend to over-estimate the forces required to push/pull as opposed to lift an object when the object was large and they perceived the object to be heavy.

SUMMARY

The data appears to satisfy the assumptions of the Wilcoxon Signed Rank Test. The second assumption of the Wilcoxon test was not explicitly satisfied since the data exhibited a positive skewness. However, the researchers feel the skewness was a result of the small sample size and,

since there existed an equal probability that the value of D_i could assume a positive or negative value, a larger sample would probably exhibit symmetry.

In performing the test of hypothesis for each of the tasks evaluated, only one task (Remove and Replace RT 220) failed to support the null hypothesis that interview and observation measurement techniques provided the same results. Further analysis of the task indicated that the respondents overestimated the forces required to be applied because of the awkward body position involved. When those steps were removed, the null hypothesis was supported. Also, when a test of hypothesis was performed with all three tasks combined, the null hypothesis was supported, both with and without the data that caused the rejection of the first hypothesis test for the RT 220.

Other findings from the research indicated that using the technical order procedures and the AFSC's Specialty Training Standard as a basis for developing the interview/observation instrument could present problems in the following areas:

1) The technical procedures do not identify which AFSC performs what actions when task accomplishment requires the coordinated effort of two or more AFSCs.

2) The AFSC's Specialty Training Standard does not include peculiar work center requirements which may result in an AFSC performing some tasks associated with another AFSC.

3) Technical order procedures may not identify all actions required to perform a given task.

4) Technical order procedures often include two or more actions combined in one step.

In addition, the size and perceived mass of an object appeared to influence an individual's estimate of the force required to position or maneuver an object.

Chapter 5

SUMMARY, CONCLUSIONS, RECOMMENDATIONS

The Air Force's present goal is to achieve approximately a fifteen percent female workforce in the noncombat Air Force Specialties by FY 1978 (4:16; 7:1). This goal was established to offset the possible shortage of men enlisting in the Air Force due to the end of the draft, and to implement the Department of Defense efforts to establish the military services as models of equal opportunity (4:1). Since women have been entering these noncombat AFSCs, a potential problem has developed in those Air Force Specialties involving heavy or very heavy manual labor (4:1). It has been documented in various reports (1; 4; 6) that women working in physically demanding AFSCs are having difficulty performing the required work. While women in AFSCs where significant physical strength and stamina are not required are doing well (6:2-3).

The lack of physical strength and stamina is not limited to women. There has always been a small portion of the male workforce assigned to AFSCs requiring heavy or very heavy manual labor who have been able to perform satisfactorily in the AFSC only because not all jobs in the AFSC require heavy manual labor. However, by indiscriminately adding large numbers of women to this minority of

smaller men in the heavy manual labor AFSCs, a potentially serious problem may occur because there are not enough jobs entailing light work to accomodate the increased numbers of personnel not physically qualified to perform the heavy work (6:1). Recognizing that the Air Force personnel assignment policies do not presently adequately consider the individual's physical ability to accomplish the work, the Aerospace Medical Research Laboratory, Human Engineering Division (AMRL/HED) has been charged with the task of developing physical and operational standards for Air Force Specialties (AFS), and to develop a means for measuring the ability of personnel to satisfy strength, stamina, and operational performance requirements (13:5; 4:26).

RESEARCH SUMMARY

This research was accomplished in coordination with AMRL/HED and was designed to evaluate whether or not personnel serving in an Air Force Specialty could provide the necessary information required to quantify, in terms of physical units of measurement, the physical demands of their work. Air Force Specialty 328X1, Avionic Navigation Systems Specialist/Technician was chosen as the pilot test AFSC after evaluating the physical demands of the AFSC, the work center's mission requirements, and the work center's

ability and willingness to support this research. The 328X1 AFSC Specialty Training Standard was used to identify the tasks which the AFSC performs and to select the three tasks which demanded heavy physical exertion on the part of the personnel performing the task. The technical orders associated with the tasks to be evaluated were used to develop the interview and observation instrument. With this instrument, sixteen assigned personnel provided quantitative estimates of the physical demands of the tasks.

The researchers compared the personnel estimates of the task's physical demands to what was determined to be the actual physical demands of each step of the tasks using the Wilcoxon Signed Rank Test. The results of the statistical tests indicated that personnel could provide the same quantitative information as that obtained through job analysis. However, it was also observed that an individual's quantitative estimates tended to be greater than that actually required when awkward body positions or difficult-to-reach work areas were involved. Furthermore, there is some evidence to suggest that an object's size and perceived mass may influence an individual's quantitative estimate.

CONCLUSIONS

There are several techniques available to measure the demands of a job. The techniques rely principally upon

an analyst monitoring the task being performed and annotating the observed physical demands on a worksheet based on some criteria consistent with the intended use of the data. The costs associated with these techniques and the time required to accomplish a relatively comprehensive study of an AFSC's physical demands becomes prohibitive when one realizes the magnitude of an undertaking to quantify the physical demands of approximately 290 Air Force Specialties. The problem of developing physical and operational standards of performance and tests for measuring the ability of personnel to satisfy the strength, stamina, and operational performance requirements of AF specialties is further complicated since many Air Force specialties are used across widely differing weapons systems, which may therefore exhibit varying physical demands. In the interest of time and cost effectiveness, it is desirable to determine alternative methods of quantifying the physical demands of an Air Force Specialty.

This research effort was an attempt to determine the feasibility of quantifying the physical demands of an AFS from the subjective estimates of personnel working in the AFSC. If this method of data collection is indeed feasible and valid, as this research effort indicates, then such a method could produce a timely and cost effective alternative to job analysis techniques.

RECOMMENDATIONS

A large scale research effort needs to be accomplished to validate the research findings. The researchers feel that a sample of sixteen respondents and three tasks is not sufficiently large enough to validate the procedure for estimating the AFSC's physical demands. Our research findings do provide evidence indicating that personnel quantitative estimates may be one credible means of identifying and quantifying physical and operational performance requirements.

Additional research also needs to be accomplished to ascertain the impact of factors such as awkward body positions, difficult-to-reach/confined work areas, size and perceived mass of objects, and other factors that may influence respondent's estimates.

APPENDIX A

SPECIALTY TRAINING STANDARD -- AFSC 328X1

DEPARTMENT OF THE AIR FORCE
Headquarters, US Air Force
Washington DC 20330

STS 328X1
(For AFSCs 32831/51/71)
12 January 1973

AVIONIC NAVIGATION SYSTEMS SPECIALIST
AND
AVIONIC NAVIGATION SYSTEMS TECHNICIAN

1. Purpose of this Specialty Training Standard (STS). As prescribed in AFR 8-13, this STS:

a. States in column 1 of attachment 1 the tasks, knowledges, and study references (SR) necessary for airmen to perform duties in the Avionic Navigation Systems ladder of the Airman Avionics Systems Career Field. These are based on the Specialty Descriptions effective 1 January 1972 in Change 8, AFM 39-1.

b. Indicates in columns 2A, 3A, and 4A of attachment 1 the minimum proficiency recommended for each task or knowledge for qualification at the 3, 5, and 7 skill level AFSCs. AFM 50-23 is the authority to change the proficiency level during JPG development when the local requirement is different from the level shown in this STS.

c. Shows in column 2A of attachment 1 the proficiency attained in Course 3ABR32831 (PDS Code AA8) described in AFM 50-5. Proficiency code for the minimum proficiency recommended for the 3 skill level AFSC and the proficiency attained in the course are the same except when dual codes are entered. When dual codes are entered, the second code shows the proficiency attained in the course.

d. Provides basis for supervisors to plan and conduct individual OJT programs.

e. Provides a convenient record of on-the-job training completed when inserted in AF Form 623, "Consolidated Training Record," and maintained in accordance with AFM 50-23.

f. Defines the knowledge requirements covered by Specialty Knowledge Tests in the Weighted Airman Promotion System.

2. Proficiency Code Key. Attachment 1 contains the Proficiency Code Key used to show proficiency level.

3. Career Development Channel of OJT. Satisfactory completion of CDC 32851 is mandatory for personnel training to AFSC 32851. Satisfactory completion of CDC 32871 and fulfillment of management training requirements specified in AFM 50-23 are mandatory for personnel training to AFSC 32871. (See Part II, Section III, ECI Catalog and Guide, for current CDC identification number for ordering purposes.)

4. Study Guidance for Weighted Airman Promotion System (WAPS). Specialty Knowledge Tests (SKTs) for promotion to E-5 are based on 5 skill level knowledge requirements. SKTs for promotion to E-6 and E-7 are based on 7 skill level requirements. SKT questions are based primarily on Career Development Courses (CDCs). However, some questions may be drawn from other references listed in this Specialty Training Standard. The CDCs for SKT study are maintained in the WAPS Study Reference Library. Other references listed should be available in the work area.

5. Recommendations. Report to ATC/TT unsatisfactory performance of individual graduates or inadequacies of this STS. Refer to specific paragraphs of this STS. See AFR 50-38.

BY ORDER OF THE SECRETARY OF THE AIR FORCE

OFFICIAL

JOHN D. RYAN, General, USAF
Chief of Staff

DWIGHT W. COVELL, Colonel, USAF
Director of Administration

1 Attachment
Qualitative Requirements

Supersedes STS 301X1, 22 December 1970 and Change 1, 20 May 1971.

THIS BLOCK IS FOR IDENTIFICATION PURPOSES ONLY		
TRAINEE		
NAME	INITIALS (In Writing)	GRADE
ORGANIZATION		
TRAINER'S NAMES AND INITIALS (In Writing)		
N/I	N/I	
N/I	N/I	

QUALITATIVE REQUIREMENTS

PROFICIENCY CODE KEY		
	SCALE VALUE	DEFINITION: The Individual
TASK PERFORMANCE LEVELS	1	Can do simple parts of the task. Needs to be told or shown how to do most of the task. (EXTREMELY LIMITED)
	2	Can do most parts of the task. Needs help only on hardest parts. May not meet local demands for speed or accuracy. (PARTIALLY PROFICIENT)
	3	Can do all parts of the task. Needs only a spot check of completed work. Meets minimum local demands for speed and accuracy. (COMPETENT)
	4	Can do the complete task quickly and accurately. Can tell or show others how to do the task. (HIGHLY PROFICIENT)
* TASK KNOWLEDGE LEVELS	a	Can name parts, tools, and simple facts about the task. (NOMENCLATURE)
	b	Can determine step by step procedures for doing the task. (PROCEDURES)
	c	Can explain why and when the task must be done and why each step is needed. (OPERATING PRINCIPLES)
	d	Can predict, identify, and resolve problems about the task. (COMPLETE THEORY)
** SUBJECT KNOWLEDGE LEVELS	A	Can identify basic facts and terms about the subject. (FACTS)
	B	Can explain relationship of basic facts and state general principles about the subject. (PRINCIPLES)
	C	Can analyze facts and principles and draw conclusions about the subject. (ANALYSIS)
	D	Can evaluate conditions and make proper decisions about the subject. (EVALUATION)

– EXPLANATIONS –

* A task knowledge scale value may be used alone or with a task performance scale value to define a level of knowledge for a specific task. (Examples: b and 1b)

** A subject knowledge scale value is used alone to define a level of knowledge for a subject not directly related to any specific task, or for a subject common to several tasks.

– This mark is used alone instead of a scale value to show that no proficiency training is provided in the course, or that no proficiency is required at this skill level.

X This mark is used alone in course columns to show that training is not given due to limitations in resources.

1. TASKS, KNOWLEDGES AND STUDY REFERENCES	PROFICIENCY LEVEL, PROGRESS RECORD AND CERTIFICATION								
	2. 3 Skill Level			3. 5 Skill Level			4. 7 Skill Level		
	A AFSC/Crs	B Date OJT Started	C Date Completed & Trainer's, Trainee's Initials	A AFSC	B Date OJT Started	C Date Completed & Trainer's, Trainee's Initials	A AFSC/Crs	B Date OJT Started	C Date Completed & Trainer's, Trainee's Initials
NOTE: Users may annotate list of SRs to identify references pending STS revision.									
1. COMMUNICATIONS SECURITY (TRANSEC)									
SR: AFP 50-47 (vol II); AFRs 205-1, 205-7									
a. Identify information as classified, unclassified, or of possible intelligence value	1b/b			2b			3c		
b. Identify official information as Top Secret, Secret, Confidential, or For Official Use Only	1b/b			2b			3c		
c. Select and recommend mode of transmission dictated by security and expediency required	1b/b			2b			3c		
d. Observe security precautions involved in voice communications	3b/b			3b			4d		
e. Safeguard classified/sensitive information and equipment	3b/b			3b			4d		
2. SUPERVISION AND TRAINING									
a. Supervision									
SR: AFR 39-6									
(1) Counsel subordinates, evaluate performance of personnel and write performance reports	-			2b			4c	NO ADVANCED COURSE	
SR: AFMs 39-62, 50-3 (chap 8); AFRs 35-32, 39-30									
(2) Orient newly assigned personnel and make work assignments	-			1a			4c		
SR: AFMs 25-1 (chap 4), 50-20 (part 3), 66-1 (chap 1, vol II)									
(3) Establish and evaluate compliance with work methods and schedules, controls, performance standards, and leave schedules	-			b			3c		
SR: AFMs 25-1 (chap 5), 50-20 (part 2); AFR 25-8									

1. TASKS, KNOWLEDGES AND STUDY REFERENCES	PROFICIENCY LEVEL, PROGRESS RECORD AND CERTIFICATION								
	2. 3 Skill Level			3. 5 Skill Level			4. 7 Skill Level		
	A AFSC/Crs	B Date OJT Started	C Date Completed & Trainer's, Trainee's Initials	A AFSC	B Date OJT Started	C Date Completed & Trainer's, Trainee's Initials	A AFSC/Crs	B Date OJT Started	C Date Completed & Trainer's, Trainee's Initials
2a(4) Interpret directives, policies, procedures, technical orders, and schematic diagrams, and resolve difficult technical problems for subordinates	-			2b			4c		
SR: AFM 50-20 (part 5); applicable technical orders									
(5) Draft or edit correspondence	-			2b			3c		
SR: AFM 66-1 (chap 2, vol V)									
(6) Supervise flight line and shop maintenance and inspections	-			2b			4c		
SR: AFMs 25-1 (chap 4), 50-20 (part 3), 66-1 (chap 2, vol V); TO 00-20-1 (sec III thru V)									
(7) Establish requirements and maintain records necessary for obtaining maintenance equipment, tools, technical data and spare parts	-			2b			3c		
SR: AFMs 66-1 (chap 3, vol V), 67-1 (chap 5 and 7, part 1, vol II); TO 00-20-3 (sec II)									
(8) Plan and maintain maintenance status boards, charts, specialist dispatch boards and dispatch forms	-			2b			4c		
SR: AFM 66-1 (chap 2, vol II; chap 3, vol V)									
(9) Supervise quality control programs and recommend methods to improve equipment performance and maintenance procedures	-			2c			3c	NO ADVANCED COURSE	
SR: AFM 66-1 (chap 3, vol II); AFR 66-44									
(10) Establish schedules and procedures for obtaining PMEL support for maintenance and calibration of test equipment	-			3b			4c		
SR: AFM 66-1 (chap 2, vol II; chap 7 and 8, vol V); TOs 00-20-10-6, 33-1-14, 33K-1-100									

1. TASKS, KNOWLEDGES AND STUDY REFERENCES	2. 3 Skill Level A AFSC/Crs	2. 3 Skill Level B Date OJT Started	2. 3 Skill Level C Date Completed & Trainer's, Trainee's Initials	3. 5 Skill Level A AFSC	3. 5 Skill Level B Date OJT Started	3. 5 Skill Level C Date Completed & Trainer's, Trainee's Initials	4. 7 Skill Level A AFSC/Crs	4. 7 Skill Level B Date OJT Started	4. 7 Skill Level C Date Completed & Trainer's, Trainee's Initials
2a(11) Locate part numbers and complete requisitions for supplies, parts, or equipment	b/-			2b			3c	NO ADVANCED COURSE	
SR: AFM 66-1 (chap 3, vol V); applicable Illustrated Parts Breakdown (-4 TO)									
(12) Evaluate maintenance and personnel qualification	-			-			3c		
SR: AFM 66-1 (chap 3, vol II); AFR 66-8									
(13) Evaluate proposed equipment modifications	-			2b			4c		
SR: AFR 57-4									
(14) Evaluate suggestions	-			2b			4c		
SR: AFM 900-4									
(15) Promote safety program	-			2b			4c		
SR: AFM 66-1 (chap 1, vol I; chap 3, vol V)									
b. Training									
(1) Plan and conduct OJT programs and training	-			3b			4c		
SR: AFMs 39-1, 50-23 (chap 5), 66-1 (chap 4, vol II; chap 3, vol V)									
(2) Establish training requirements and recommend personnel for training	-			1b			3c		
SR: AFMs 35-8, 39-4, 50-5 (sec I and V); AFRs 50-9, 50-12, 50-29, 50-37, 50-39									
(3) Maintain training records and charts and evaluate training programs and progress	-			3c			4c		
SR: AFMs 50-23 (chap 5 and 6), 66-1 (chap 1 and 3, vol V)									
(4) Develop, administer and score tests	-			2b			3c		
SR: AFM 35-8 (chap 1, 4, 17, 20)									
3. MAINTENANCE MANAGEMENT									
a. Functions and responsibilities of the Chief of Maintenance	A			B			B		
SR: AFM 66-1 (chap 1, vol II)									

1. TASKS, KNOWLEDGES AND STUDY REFERENCES	PROFICIENCY LEVEL, PROGRESS RECORD AND CERTIFICATION								
	2. 3 Skill Level			3. 5 Skill Level			4. 7 Skill Level		
	A AFSC/Crs	B Date OJT Started	C Date Completed & Trainer's, Trainee's Initials	A AFSC	B Date OJT Started	C Date Completed & Trainer's, Trainee's Initials	A AFSC/Crs	B Date OJT Started	C Date Completed & Trainer's, Trainee's Initials
3b. Basic functions of management units that make up the Chief of Maintenance's staff	A			B			B		
SR: AFM 66-1 (chap 2, 3, and 4, vol II)									
c. Man-hour reporting system	A			B			C		
SR: AFM 66-1 (chap 4, vol II)									
d. Equipment classification designators	A			B			C		
SR: AFM 300-4 (vol XI)									
e. Job control number	A			B			C		
SR: AFM 66-1 (chap 2, vol II)									
f. Maintenance data collection	A			B			C		
SR: AFMs 66-1 (chap 1 thru 4, vol II), 66-267; TO 00-20 series									
g. Processing and controlling of materiel	A			B			C		
SR: AFM 66-1 (chap 3, vol II)									
4. MAINTENANCE AND INSPECTION SYSTEM AND FORMS							NO ADVANCED COURSE		
a. Inspection and maintenance systems	B			B			C		
SR: AFM 66-1 (chap 3, vol II; chap 3, vol V); TOs 00-20-1, 00-20-5									
b. Use man-hour reporting forms	-			3c			3c		
SR: AFMs 66-1 (chap 4, vol II), 66-264									
c. Use maintenance data collection forms	2b			3c			3c		
SR: AFM 66-1 (chap 3 and 4, vol II); TOs 00-20-2-1, 00-20-2-2									
d. Materiel deficiency reporting system	A			B			C		
SR: TO 00-35D-54									
e. Prepare reports of unsatisfactory performance of equipment	-			3c			4c		
SR: TO 00-35D-54									

1. TASKS, KNOWLEDGES AND STUDY REFERENCES	PROFICIENCY LEVEL, PROGRESS RECORD AND CERTIFICATION								
	2. 3 Skill Level			3. 5 Skill Level			4. 7 Skill Level		
	A AFSC/Crs	B Date OJT Started	C Date Completed & Trainer's, Trainee's Initials	A AFSC	B Date OJT Started	C Date Completed & Trainer's, Trainee's Initials	A AFSC/Crs	B Date OJT Started	C Date Completed & Trainer's, Trainee's Initials
4f. Research maintenance reports to determine methods for improving procedures at local activity	-			2b			3c		
SR: AFM 66-1 (chap 3, vol. II); AFR 66-44									
g. Review completed maintenance and inspection forms for accuracy	-			3b			4c		
5. TECHNICAL PUBLICATIONS									
a. Air Force Technical Order system	A			B			C		
SR: AFR 8-2; TO 00-5-1									
b. Use technical orders when maintaining, modifying, or inspecting navigation equipment and systems	2b			3c			4c		
SR: TO 00-5-1; TOs for specific equipment									
c. Use standard publications to obtain information pertinent to maintenance	-			2b			3c	NO ADVANCED COURSE	
SR: AFRs 0-2, 0-9, 0-10, subject series 50, 52, 66, 127									
d. Report technical order deficiencies	2b/b			3c			4c		
SR: TO 00-5-1 (sec VIII)									
6. ELECTRONIC PRINCIPLES APPLICABLE TO TASKS LISTED IN THIS STS	B			B			B		
SR: AFM 52-8; TO 31-1-141 series									
7. ANALYSIS OF AVIONIC NAVIGATION EQUIPMENT									
SR: Applicable 12 series TOs									
a. Purpose, description, general principles of operation, and characteristics of electronic navigation equipment	B			C			C		
b. Perform system tie-in, block diagram data flow, and circuit analysis of avionic navigation equipment	2b			3c			4c		

1. TASKS, KNOWLEDGES AND STUDY REFERENCES	PROFICIENCY LEVEL, PROGRESS RECORD AND CERTIFICATION								
	2. 3 Skill Level			3. 5 Skill Level			4. 7 Skill Level		
	A AFSC/Crs	B Date OJT Started	C Date Completed & Trainer's, Trainee's Initials	A AFSC	B Date OJT Started	C Date Completed & Trainer's, Trainee's Initials	A AFSC/Crs	B Date OJT Started	C Date Completed & Trainer's, Trainee's Initials
7c. Principles of operation, capabilities, characteristics, and substitutional suitability of authorized test equipment	A			C			C		
SR: Stock Lists (applicable SL-ISG); TOs (applicable 33 series)									
8. MAINTENANCE OF INSTALLED EQUIPMENT									
SR: Applicable 1 series TOs									
a. Apply safety precautions in and around aircraft	2c/b			3c			4c		
b. Observe RF radiation hazard precautions	2c/b			3c			4c		
SR: AFM 161-7									
c. Operate all switches and controls necessary to check installed electronic navigation equipment	1b/-			2b			3c		
d. Check installed electronic navigation equipment visually and by use of flight line or built-in test equipment (BITE)	2b			3c			4c		
e. Isolate malfunctions of installed equipment to a line replaceable unit (LRU) or defective wiring	2b			3c			4c		
f. Remove and replace defective LRUs	2b/b			3c			4c		
g. Safety wire components and attach bonding straps	2b			3c			4c		
h. Install cables in aircraft	2b/b			3c			4c		
i. Repair installed coaxial and multiconductor cables	2b			3c			4c		
j. Adjust installed equipment to TO specifications	2b			3c			4c		
k. Utilize aircraft wiring diagrams during maintenance	2b			3c			4c		
l. Post entries on applicable maintenance and inspection forms and records	2b			3c			4c		
SR: TO 00-20 series									
9. INTERMEDIATE LEVEL SHOP MAINTENANCE									
SR: Applicable 12 series TOs									
a. Use appropriate safety procedures in shop maintenance	2b			3c			4c		

NO ADVANCED COURSE

1. TASKS, KNOWLEDGES AND STUDY REFERENCES	PROFICIENCY LEVEL, PROGRESS RECORD AND CERTIFICATION								
	2. 3 Skill Level			3. 5 Skill Level			4. 7 Skill Level		
	A AFSC/Crs	B Date OJT Started	C Date Completed & Trainer's, Trainee's Initials	A AFSC	B Date OJT Started	C Date Completed & Trainer's, Trainee's Initials	A AFSC/Crs	B Date OJT Started	C Date Completed & Trainer's, Trainee's Initials
9b. Fabricate or maintain test bench mockups	-			3c			4c		
c. Interconnect bench test equipment with LRU in accordance with applicable technical orders	2b			3c			4c		
d. Determine operating condition of test equipment	2b			3c			4c		
e. Make visual inspections and minimum performance test of LRUs of the following systems									
(1) Radio compass	2b			3c			4c		
(2) LORAN (see Note 1)	2b/-			3c			4c		
(3) Electronic altimeters									
(a) Frequency modulated (FM)	2b/b			3c			4c		
(b) Pulse modulated (PM)	2b			3c			4c		
(4) VOR	2b			3c			4c		
(5) ILS	2b			3c			4c		
(6) TACAN	2b			3c			4c		
(7) Search and weather radar	2b			3c			4c		
(8) Beacon	2b			3c			4c	NO ADVANCED COURSE	
(9) IFF/SIF	2b			3c			4c		
(10) SHORAN/SHIRAN (see Note 1)	-			2b			3c		
(11) Radiation detection instruments (see Note 1)	-			2b			3c		
(12) Marker beacon	2b/-			3c			4c		
f. Isolate malfunctioning subassemblies or discrete components of system LRUs including									
(1) Radio compass	2b			3c			4c		
(2) LORAN (see Note 1)	2b/-			3c			4c		
(3) Electronic altimeters									
(a) Frequency modulated (FM)	2b/b			3c			4c		
(b) Pulse modulated (PM)	2b			3c			4c		
(4) VOR	2b			3c			4c		
(5) ILS	2b			3c			4c		
(6) TACAN	2b			3c			4c		
(7) Search and weather radar	2b			3c			4c		

1. TASKS, KNOWLEDGES AND STUDY REFERENCES	PROFICIENCY LEVEL, PROGRESS RECORD AND CERTIFICATION								
	2. 3 Skill Level			3. 5 Skill Level			4. 7 Skill Level		
	A AFSC/Crs	B Date OJT Started	C Date Completed & Trainer's, Trainee's Initials	A AFSC	B Date OJT Started	C Date Completed & Trainer's, Trainee's Initials	A AFSC/Crs	B Date OJT Started	C Date Completed & Trainer's, Trainee's Initials
9f(8) Beacon	2b/b			3c			4c		
(9) IFF/SIF	2b			3c			4c		
(10) SHORAN/SHIRAN (See Note 1)	-			2b			3c		
(11) Radiation detection instruments (see Note 1)	-			2b			3c		
(12) Marker beacon	2b/-			3c			4c		
g. Remove and replace or repair defective subassemblies using hand tools and soldering equipment	2b/1b			3c			4c		
h. Align and adjust to TO specifications LRUs of systems including									
(1) Radio compass	2b			3c			4c		
(2) LORAN (see Note 1)	2b/-			3c			4c		
(3) Electronic altimeters									
(a) Frequency modulated (FM)	2b/b			3c			4c		
(b) Pulse modulated (PM)	2b			3c			4c		
(4) VOR	2b			3c			4c		
(5) ILS	2b			3c			4c		
(6) TACAN	2b			3c			4c	NO ADVANCED COURSE	
(7) Search and weather radar	2b			3c			4c		
(8) Beacon	2b			3c			4c		
(9) IFF/SIF	2b			3c			4c		
(10) SHORAN/SHIRAN (see Note 1)	-			2b			3c		
(11) Radiation detection instruments (see Note 1)	-			2b			3c		
(12) Marker beacon	2b/-			3c			4c		
i. Perform preinstallation test on new or replacement LRUs	2b/1a			3c			4c		
j. Modify equipment in accordance with applicable directives and work orders	2b/a			3c			4c		
k. Select and use common test equipment such as voltmeters, multimeters, oscilloscopes, signal generators, power meters, frequency meters and counters, vacuum tube and transistor checkers	2b			3c			4c		
SR: Applicable 33 series TOs									

1. TASKS, KNOWLEDGES AND STUDY REFERENCES	PROFICIENCY LEVEL, PROGRESS RECORD AND CERTIFICATION								
	2. 3 Skill Level			3. 5 Skill Level			4. 7 Skill Level		
	A AFSC/Crs	B Date OJT Started	C Date Completed & Trainer's, Trainee's Initials	A AFSC	B Date OJT Started	C Date Completed & Trainer's, Trainee's Initials	A AFSC/Crs	B Date OJT Started	C Date Completed & Trainer's, Trainee's Initials
91. Use peculiar test equipment	2b			3c			4c	NO ADVANCED COURSE	
SR: Applicable 33 series TOs									
m. Perform intermediate level maintenance of installed and applicable items of peculiar test equipment	2b/a			3c			4c		
SR: TOs 33-1-14, 33 series equipment TOs, 33K-1-100									
10. PREVENTIVE MAINTENANCE									
SR: Applicable 12 series TOs									
a. Practice corrosion control in electronic systems and interconnections	2b/a			3c			4c		
b. Clean and lubricate equipment and components	2b/a			3c			4c		
c. Perform navigation equipment inspection in accordance with applicable TOs and maintenance directives	2b/b			3c			4c		

NOTE 1: Proficiency levels included for these systems apply only to those organizations having this equipment. All training on these elements will be accomplished by FTD/OJT or through special training requested in accordance with AFR 50-9.

APPENDIX B

INTERVIEW/OBSERVATIONS WORKSHEETS

OBSERVATION WORKSHEET

Sheet 1 of 1
Date:

No. Personnel Performing Task:

Task No:

Task Element Description: Remove and Replace RT 220/ARN21 TACAN from KC-135

Activity:	Non-Significant	Force Categories: Lift	Lower	Torque	Turn	Push	Pull	Carry	Hold	Other	Measurements: Distance	Time	Frequency	Power	Force	Force Time	Force Distance	Remarks:
11-55 RECEIVER-TRANSMITTER - REMOVAL a. Loosen the hold-down clamps securing the receiver-transmitter to the mount.																		
b. Remove unit from mount.																		
11-56 RECEIVER-TRANSMITTER - INSTALL. a. Position receiver-transmitter in mount and check that electrical connector mates properly.																		
b. Engage, tighten and lockwire hold-down clamps.																		

OBSERVATION WORKSHEET		Sheet 1 of 2 Date:
No. Personnel Performing Task:	Task No:	Task Element Remove Search Radar Antenna Description: from KC-135

Activity:	Non-Significant	Force Categories: Lift	Lower	Torque	Turn	Push	Pull	Carry	Hold	Other	Measurements: Distance	Time	Frequency	Power	Force	Force Time	Force Distance	Remarks:
16-106 SEARCH RADAR ANTENNA - REMOVAL a. Release the 18 nose radome fasteners by turning studs one-half turn counter-clockwise. Studs will pop up when released.																		
b. Have an assistant hold radome while stud assemblies are pulled from radome with pliers.																		
c. Carefully remove radome from bulkhead.																		
d. Remove the four mounting screws connecting the waveguide to the top of the antenna.																		
e. Disconnect the electrical connectors																		

OBSERVATION WORKSHEET

Sheet 2 of 2

Date:

No. Personnel Performing Task:	Task No:	Task Element Description: Remove Search Radar Antenna from KC-135

Activity:	Non-Significant	Force Categories: Lift	Lower	Torque	Turn	Push	Pull	Carry	Hold	Other	Measurements: Distance	Time	Frequency	Power	Force	Force Time	Force Distance	Remarks:
f. Remove the center bolt and lockwasher from each of the three shockmounts.																		
g. Remove radar antenna from aircraft.																		

OBSERVATION WORKSHEET

Sheet 1 of 2
Date:

No. Personnel Performing Task:	Task No:	Task Element Description: Replace Search Radar Antenna in KC-135

Activity:	Non-Significant	Force Categories: Lift	Lower	Torque	Turn	Push	Pull	Carry	Hold	Other	Measurements: Distance	Time	Frequency	Power	Force	Force Time	Force Distance	Remarks:
16-107 SEARCH RADAR ANTENNA - INSTALLATION a. With the nose radome removed, put the antenna in place.																		
b. Install the center bolt and lockwashers in each of the three shockmounts.																		
c. Connect the electrical connectors																		
d. Connect the waveguide to the top of the antenna by installing the four mounting screws.																		
e. Carefully locate nose radome in place.																		

OBSERVATION WORKSHEET — Sheet 2 of 2 — Date:

No. Personnel Performing Task:	Task No:	Task Element Description: Replace Search Radar Antenna in KC-135

Activity:	Non-Significant	Force Categories: Lift	Lower	Torque	Turn	Push	Pull	Carry	Hold	Other	Measurements: Distance	Time	Frequency	Power	Force	Force Time	Force Distance	Remarks:
f. Check that socket is centered under hole near top of radome.																		
g. Insert bushing of stud assembly in hole.																		
h. Engage top stud by pushing inward to bottom and turning one-quarter turn clockwise.																		
i. Repeat steps "f" thru "h" for stud at bottom of radome opposite to first stud installed. Next install and engage left and right opposing studs. Continue until all studs are engaged.																		
j. Torque studs to 40($\pm$ 5) pounds-inch.																		

OBSERVATION WORKSHEET

Sheet 1 of 2
Date:

No. Personnel Performing Task:

Task No:

Task Element Description: Remove RT 259/APN59 from KC-135

Activity:	Non-Significant	Force Categories: Lift	Lower	Torque	Turn	Push	Pull	Carry	Hold	Other	Measurements: Distance	Time	Frequency	Power	Force	Force Time	Force Distance	Remarks:
16-90 SEARCH RADAR RECEIVER-TRANSMITTER - REMOVAL Position B-4 maintenance stand.																		
a. Turn off the radar pressurizing system by placing the system power switch on the radar pressurizing control panel on the navigator's radar control console in "OFF" position.																		
b_1 Disconnect the pressurizing line.																		
b_2 Remove the four mounting screws connecting the waveguide to the receiver-transmitter.																		
c. Disconnect the electrical connectors																		

OBSERVATION WORKSHEET			Sheet 2 of 2 Date:
No. Personnel Performing Task:	Task No:	Task Element Description:	Remove RT 289/APN59 from KC-135

Activity:	Non-Significant	Force Categories: Lift	Lower	Torque	Turn	Push	Pull	Carry	Hold	Other	Measurements: Distance	Time	Frequency	Power	Force	Force Time	Force Distance	Remarks:
d_1 Disconnect the three ground straps from the mounting ring.																		
d_2 Remove the three bolts and hardware from the receiver-transmitter mount brackets.																		
e_1 Carefully lift the receiver-transmitter from the mounting ring so as not to cause possible damage to the receiver-transmitter or the surrounding equipment																		
e_2 Remove receiver-transmitter from lower nose compartment.																		

OBSERVATION WORKSHEET

Sheet 1 of 2

Date:

No. Personnel Performing Task:

Task No:

Task Element Description: Replace RT 280/APN59 in KC-135

Activity:	Non-Significant	Force Categories: Lift	Lower	Torque	Turn	Push	Pull	Carry	Hold	Other	Measurements: Distance	Time	Frequency	Power	Force	Force Time	Force Distance	Remarks:
16-91 SEARCH RADAR RECEIVER-TRANSMITTER - INSTALLATION.																		
a_1 Carefully insert the receiver-transmitter into the lower nose compartment.																		
a_2 Install receiver-transmitter into the mounting ring with the three mount brackets coming to rest on the shock mounts.																		
b_1 Install the three mount bolts and hardware in the three mounting brackets on the receiver-transmitter.																		
c. Connect the electrical connectors																		
d. Connect the waveguide to the receiver-transmitter by installing the four mounting screws.																		

OBSERVATION WORKSHEET																		Sheet 2 of 2 Date:
No. Personnel Performing Task:			Task No:						Task Element Description: Replace RT 289/APN59 in KC-135									
		Force Categories									Measurements							
Activity:	Non-Significant	Lift	Lower	Torque	Turn	Push	Pull	Carry	Hold	Other	Distance	Time	Frequency	Power	Force	Force Time	Force Distance	Remarks:
e. Connect the pressurizing line using new O-ring if needed.																		

APPENDIX C

TECHNICAL ORDER PROCEDURES

Technical Order Procedural
Steps, RT 220

11-55. RECEIVER-TRANSMITTER -- REMOVAL

a. Loosen the hold-down clamps securing the receiver-transmitter to the mount.

b. Remove unit from mount.

11-56. RECEIVER-TRANSMITTER -- INSTALLATION

a. Position receiver-transmitter in mount and check that electrical connector mates properly.

b. Engage, tighten and lockwire hold-down clamps.

Technical Order Procedural Steps,
Search Radar Antenna

16-106. SEARCH RADAR ANTENNA -- REMOVAL.

a. Release the 18 nose radome fasteners by turning studs...one-half turn counter-clockwise. Studs will pop up when released.

b. Have an assistant hold radome while stud assemblies are pulled from radome with pliers. Stud assemblies must be removed completely because projecting heads of released studs do not clear the radome mounting clips. Use care when removing stud assemblies to avoid deforming heads of studs or damaging snap rings which retain studs...in bushings....

c. Carefully remove radome from bulkhead.

d. Remove the four mounting screws connecting the waveguide to the top of the antenna.

e. Disconnect the electrical connectors.

f. Remove the center bolt and lockwasher from each of the three shockmounts.

C A U T I O N

Do not, at any time, grasp the antenna reflectors or feed horn in order to lift the antenna. Do not place the antenna with its weight resting on any of the microwave component parts.

16-107. SEARCH RADAR ANTENNA -- INSTALLATION.

a. With the nose radome removed, put the antenna in place. Observe the "CAUTION" of paragraph 16-106.

b. Install the center bolt and lockwasher in each of three shockmounts. The airplane mount is designed to align the antenna to the airplane

16-107. (Continued)

heading within $\pm 0.5^\circ$ with its spinning axis perpendicular within $\pm 1^\circ$ to a horizontal plane passing through the roll axis of the ' airplane.

c. Connect the electrical connectors.

d. Connect the waveguide to the top of the antenna by installing the four mounting screws.

e. Carefully locate nose radome in place.

N O T E

If radome has not been installed previously on airplane, install per paragraph 16-108.

f. Check that socket...is centered under hole near top of radome. Use a screwdriver to center socket if necessary.

g. Insert bushing...of stud assembly in hole.

C A U T I O N

Do not pound on stud to force bushing into hole. If stud is not aligned with socket of receptacle, it is possible to break receptacle cage...by pounding on stud.

h. Engage top stud by pushing inward to bottom and turning one-quarter turn clockwise. Stud will spring up if not engaged. If stud does not engage, the receptacle must be reset by turning the stud counterclockwise. Do not turn the stud counterclockwise more than necessary to allow engagement.

i. Repeat steps "f" through "h" for stud at bottom of radome opposite to first stud installed. Next install and engage left and right opposing studs. Continue until all studs are engaged.

j. Torque studs to 40 ($\pm$5) pound-inches.

Technical Order Procedural
Steps, RT 289

16-90. SEARCH RADAR RECEIVER-TRANSMITTER -- REMOVAL.

WARNING

The receiver-transmitter weighs approximately 74 pounds and should not be removed from the airplane without use of proper support equipment such as a B-4 or equivalent maintenance stand.

a. Turn off the radar pressurizing system by placing the system power switch on the radar pressurizing control panel on the navigator's radar control console in "OFF" position.

b. Disconnect the pressurizing line and remove the four mounting screws connecting the waveguide to the receiver-transmitter.

c. Disconnect the electrical connectors.

d. Disconnect the three ground straps from the mounting ring and remove the three bolts and hardware from the receiver-transmitter mount brackets.

e. Carefully lift the receiver-transmitter from the mounting ring so as not to cause possible damage to the receiver-transmitter of the surrounding equipment and remove from lower nose compartment.

CAUTION

When the receiver-transmitter is removed, the waveguide is exposed and may be damaged. If a replacement receiver-transmitter is not immediately available, a protective barrier should be installed over the exposed end of the waveguide.

16-91. SEARCH RADAR RECEIVER-TRANSMITTER -- INSTALLATION.

W A R N I N G

The receiver-transmitter weighs approximately 74 pounds and should not be installed in the airplane without use of proper support equipment such as a B-4 or equivalent maintenance stand.

a. Carefully insert the receiver-transmitter into the lower nose compartment and install it into the mounting ring with the three mount brackets coming to rest on the shock mounts.

b. Install the three mount bolts and hardware in the three mounting brackets on the receiver-transmitter. Connect the three ground straps to the mounting ring.

c. Connect the electrical connectors.

d. Connect the waveguide to the receiver-transmitter by installing the four mounting screws.

e. Connect the pressurizing line using new O-ring if needed.

APPENDIX D

INTERVIEW BRIEFING

I am conducting research in an attempt to determine how accurately you and your co-workers can estimate the forces you apply in doing your work; the weights you lift and carry; the distance and time over which these forces are applied.

I have selected three "Remove and Replace" maintenance tasks which require physical exertion on your part. I have developed for each of these tasks a worksheet which identifies the steps performed in accomplishing the task. This worksheet is based on the aircraft technical order component removal and replacement procedures. I want you to estimate the forces, distances, and times involved in performing these tasks and I will record your estimates of the forces applied, weights handles, distance, and time.

Identification of Force Categories--As we go through each step in the component removal and replacement procedure, I want you to first describe what you are doing. That is, I want you to describe whether you are lifting or lowering an object; applying a force to loosen or tighten something; turning an item to position it; perhaps pushing or pulling something; or, carrying or holding an item.

Estimation of Force/Weight, Distance, Time--After you have described what you are doing in this step, I

want you to estimate how many pounds you have lifted for example, or perhaps the force you have applied to tighten something. Once this is done, I want you to estimate the distance in feet/inches, or fractions of feet/inches as you feel are appropriate, over which these forces were applied or the weights handled. I then want you to estimate the time in minutes/seconds, or fractions of minutes/seconds, over which you were applying the force.

Do you have any questions in regard to what I am asking you to do?

(From this point on, the interview was tailored to the individual being interviewed and the task being evaluated.)

APPENDIX E

SAMPLE COMPUTATIONS

SUMMARIZED DATA		STANDARD		INDEX	$D_{\text{Activity } A_1}$	RANK
Step 1 - Remove RT220						
$\bar{X}_{Force}$	22.500	Force	3.75	3.750	1.7287	43
S_{Force}	13.887	Time	5.0	3.333	1.5325	41.5
$\bar{X}_{Time}$	7.125	Index	0.075	3.333	1.5325	41.5
S_{Time}	3.875			2.500	1.1406	36
$\bar{X}_{Index}$	3.445			8.333	3.8843	48
S_{Index}	2.126			1.333	0.5917	17
				3.000	1.3758	40
				2.000	0.9055	31
Step 2 - Remove RT220						
$\bar{X}_{Force}$	47.938	Force	50.0	26.667	0.1343	3
S_{Force}	12.068	Distance	7.0	42.250	0.7622	22
$\bar{X}_{Distance}$	6.875	Time	15.0	10.000	-0.5372	-15
$S_{Distance}$	3.832	Index	23.333	18.750	-0.1846	- 5
$\bar{X}_{Time}$	23.621			54.000	1.2356	38
S_{Time}	29.980			22.500	-0.0336	- 1
$\bar{X}_{Index}$	27.128			6.667	-0.6715	-19.5
S_{Index}	24.820			6.667	-0.6715	-19.5
				0.9167	-0.9032	-30
				6 000	-0.6983	-21
				3.348	-0.8052	-25
				93.333	2.8203	46
				16.667	-0.2686	- 9
				53.125	1.2003	37
				34.667	0.4566	12
				38.500	0.6111	18
Step 1 - Replace RT220						
$\bar{X}_{Force}$	47.750	Force	50.0	20.000	0.0341	2
S_{Force}	12.482	Distance	7.0	37.750	1.0009	33
$\bar{X}_{Distance}$	6.250	Time	18.0	10.000	-0.5797	-16
$S_{Distance}$	3.061	Index	19.444	11.733	-0.4733	-14
$\bar{X}_{Time}$	25.875			27.000	0.4638	13
S_{Time}	28.556			16.000	-0.2114	- 6
$\bar{X}_{Index}$	19.488			7.000	-0.7638	-23
S_{Index}	16.292			6.667	-0.7842	-24
				2.750	-1.0247	-34
				6.000	-0.8252	-28
				5.133	-0.8784	-29
				66.667	2.8985	47
				25.000	0.3410	10
				15.441	-0.2457	- 8
				34.667	0.9344	32
				22.000	0.1569	4
Step 2 - Replace RT220						
$\bar{X}_{Force}$	28.125	Force	3.75	4.375	1.1211	35
S_{Force}	16.022	Time	6.0	3.333	0.8096	26.5
$\bar{X}_{Time}$	6.875	Index	0.625	3.333	0.8096	26.5
S_{Time}	4.051			2.000	0.4111	11
$\bar{X}_{Index}$	4.922			5.000	1.3079	39
S_{Index}	3.345			1.333	0.2117	7
				10.000	2.8027	44.5
				10.000	2.8027	44.5

Sample Computation of $D_{Activity\ A_1}$:

$$D_{Activity\ A_1} = \frac{Y_{Estimated\ index\ of\ A_1} - X_{Standard\ index\ of\ A_1}}{S_{Estimated\ index\ of\ A_1}}$$

$$1.7287 = \frac{3.750 - 0.075}{2.126}$$

Test of Hypothesis:

Number of D_1 values: 48

Sum of R^+ ranks: 849

Sum of R^- ranks: 327

Lower Critical Limit ($W_{0.025}$): 396.9

Upper Critical Limit ($W_{0.975}$): 779.1

Decision Rule: Reject H_0 if at the $\alpha = 0.05$ significance level if R exceeds $W_{0.975}$, or R is less then $W_{0.025}$, otherwise accept H_0.

Hypothesis:

$H_0: \mu_x = \mu_y$

$H_1: \mu_x \neq \mu_y$

$R < W_{0.025}$

$327 < 396.9$

Reject H_0; accept H_1

$$W_{\alpha/2} = (n(n+1)/4) + (\pm Z_{\alpha/2})\sqrt{n(n+1)(2(n+1)/24}$$

$W_{0.025} = 396.9$

$W_{0.975} = 779.1$

SELECTED BIBLIOGRAPHY

A. REFERENCES CITED

1. Cappes, Thomas E. "Physical Capacity of Females to Perform Heavy Craft Skills in the United States Air Force." Unpublished master's thesis, Air University, Maxwell Air Force Base, Alabama, May, 1977.

2. Chapanis, Alphonse. Man-Machine Engineering. Belmont, California: Wadsworth Publishing Co., Inc., 1965.

3. Chapanis, Alphonse. Research Techniques in Human Engineering. Baltimore, Maryland: John Hopkins Press, 1959.

4. Comptroller General of the United States. Job Opportunities for Women in the Military: Progress and Problems. Washington: Government Printing Office, 1976.

5. Department of the Air Force. "On-The-Job Training," Air Force Manual 50-23, Headquarters U. S. Air Force, Washington, D. C., 15 August 1974.

6. Deputy Inspector General for Inspections and Safety, USAF. Report of the Inspection and Utilization of Women in the Air Force, PN 76-608 18 August 1975-28 May 1976, Norton Air Force Base, California.

7. Design Study to Determine Methods for Establishing Criteria for Assigning Personnel to Air Force Jobs Requiring Heavy/Very Heavy Work. PR: FY8990-77-00086, USAF/AMRL/HED, Wright Patterson AFB, Ohio.

8. Fleishman, E. A. Evaluating Physical Abilities Required by Jobs. Chicago: Science Research Associates, 1975.

9. Fleishman, E. A. The Structure and Measurement of Physical Fitness. Englewood Cliffs, New Jersey: Prentice-Hall Inc., 1964.

10. Hanman, Bert. Physical Capacities and Job Placement. Stockholm, Sweden: Nordisk Rotograuyr, 1951.

11. Headquarters, Air Force Systems Command. Design Handbook, Series 1-0, General, AFSC DH 1-3 Personnel Subsystems, Wright-Patterson AFB, Ohio, 1 January 1972 (Revision 6 dated 1 January 1975).

12. International Labor Office. Introduction to Work Study. 4th ed, Switzerland: Impressions Couleurs Weber, 1974.

13. Koym, Kenneth G. Development of Physical Demand Profiles for Four Airmen Career Ladders. AFHRL-TR-75-67. Lackland AFB, Texas: Occupational and Manpower Research Division, Air Force Human Resources Laboratory, November, 1975.

14. Lawrence, Captain Fredrick P., USAF. Instructor of Quantitative Methods, Department of Quantitative Management, School of Systems and Logistics, Air Force Institute of Technology (AU), Wright Patterson AFB, Ohio. Personal interviews. May through August, 1977.

15. McCormick, Ernest J. Human Factors Engineering. New York: McGraw-Hill, Inc., 1964.

16. Medical Examinations and Medical Standards. Air Force Regulation 160-43, Headquarters, U. S. Air Force, Washington, D. C.

17. Mundel, M. E. Motion and Time Study, Principles and Practices. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1970.

18. Netter, John and others. Fundamental Statistics for Business and Economics. 4th ed. Boston: Allyn and Bacon, Inc., 1973.

19. Phaffenberger, Roger C. and James H. Patterson. Statistical Methods for Business and Economics. Homewood, Illinois: Richard D. Irwin, Inc., 1977.

20. "Physical Standards for Women Assigned to Strenuous Jobs," A conference report, Yellow Springs, Ohio: Webb Associates, Inc., January 20-21, 1975.

21. Secretary of the Air Force. "Organizational (Flight line) Maintenance Instructions: Radio, Communication and Navigation Systems." A technical manual, T.O. IC-135A-2-11-1, Washington: Government Printing Office, 25 July 1965 (Revision 36 dated 20 February 1977).

22. Siegel, Sidney. Nonparametric Statistics for the Behavioral Sciences. New York: McGraw-Hill Book Company, Inc., 1956.

23. Trimeloni, Colonel B. D. "The Role of Women in the Air Force," address to the International Women's Year Luncheon, July 10, 1975, Published in the Supplement to the Air Force Policy Letter for Commanders, September, 1975, pp. 8-12.

24. U. S. Department of Labor, Manpower Administration Office. Supplement to the Dictionary of Occupational Titles: Selected Characteristics of Occupations, (Physical Demands Working Conditions, Training Time), Washington, D. C.: U. S. Government Printing Office, 1966.

B. RELATED SOURCES

Abruzzi, A. Work, Workers, and Work Measurement. Morningside Heights, New York: Columbia University Press, 1956.

Astrand, P. O., and K. Rodahl. Work Physiology. McGraw-Hill, 1970.

Bayha, F. and D. Karger. Engineered Work Measurement. New York, New York: The Industrial Press, 1965.

Caldwell, L. S., et. al. "A Proposed Standard Procedure for Static Muscle Strength Testing," American Industrial Hygiene Association Journal, 1974, Vol. 35, No. 4, pp. 201-206.

Christensen, J. M. "Human Factors Engineering Considerations in System Development," A technical report HMRL-TR-69-82, Aerospace Medical Research Laboratory, Aerospace Medical Division, Air Force Systems Command, Wright Patterson AFB, Ohio.

Chu, D., E. Noorblom, and others. "Physical Standards in an All-Volunteer Force," Report No. R-1347-ARPA/DDPAE, Santa Monica, Cal.: Rand Corporation, April, 1974.

Clark, C., and R. C. Williges. "RSM Design Modifications for Human Performance Research," Human Factors, 15, 1973, pp. 295-310.

Clarke, H. H. Muscular Strength and Endurance in Men. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1966.

Cooper, K. H. The New Aerobics. New York: Evans, 1970.

Department of Defense. Human Engineering Design Criteria For Military Systems Equipment and Facilities. MIL-STD-1472B, Washington, D. C., 31 December 1974.

Ducharme, R. "Problem Tools for Women," Industrial Engineering, Vol. 7, No. 9, 1975, pp. 46-50.

Germain, G. S., and C. G. Browne, and R. M. Bellows. "Measuring Men and Jobs, Criteria for Physical Analysis Forms," Personnel and Guidance Journal, 31, 1953, pp. 245-249.

Glumm, M. "The Female in Military-Equipment Design," Technical Memorandum 13-76, U. S. Army Human Engineering Laboratory, Aberdeen Proving Ground, Maryland, April, 1976.

Hansen, B. Work Sampling for Modern Management. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1960.

Hunicker, P. and R. J. Donelly. "Instruments to Measure Strength," Research Quarterly, 26, 1955, pp. 408-420.

Hunsicker, P. A. and G. Greey. "Studies in Human Strength," Research Quarterly, 28, 1957, pp. 109-122.

Kenyon, R. and others. "Analyzing Work Measurement Data," Industrial Engineering, Vol. 7, No. 12, 1975, pp. 27-33.

Kerlinger, Fred N. Foundations of Behavioral Research. New York: Holt, Rinehart and Winston, Inc., 1973.

Khalil, T. and M. A. Ayoub. "Applied Ergonomics," Industrial Engineering, Vol. 8, No. 4, 1976, pp. 26-31.

Konz, S., S. Dey, and C. Bennett. "Forces and Torques in Lifting," Human Factors, 15, 1973, pp. 237-245.

Kroemer, K. H. E. "Human Strength: Terminology, Measurement, and Interpretation of Data," Human Factors, 12, 1970, pp. 297-313.

Kroemer, K., and J. Howard. "Towards Standardization of Muscle Strength Testing," Technical report AMRL-TR-70-124, Aerospace Medical Research Laboratory, Wright Patterson AFB, Ohio.

Marks, M. R., and M. E. Hook. "Development of a Standard List of Work Requirements in Airman Specialties," PRL-TR-63-19, AD-424 932, Lackland AFB, Texas: Personnel Research Laboratory, Aerospace Medical Division, August, 1963.

Ryan, T. Work and Effort, The Psychology of Production. New York: The Ronald Press Company, 1947.

Simonson, E. Physiology of Work Capacity and Fatigue. (ed) Springfield, Illinois: Charles E. Thomas, 1971.

Smith, L. E., and D. K. Edwards. "Prediction of Muscular Endurance (work performance) from Individual Difference in Initial and Post-Training Increments in Static Strength," Human Factors, 10, 1968, pp. 345-350.

Swain, A. D. "Design of Industrial Jobs a Worker Can and Will Do," Human Factors, 15, 1973, pp. 129-136.

Teichner, W. H. and D. E. Olson. "A Preliminary Theory of the Effects of Task and Environmental Factors on Human Performance," Human Factors, 13, 1971, pp. 295-344.

Theologus, G. and E. A. Fleishman. Development of a Taxonomy of Human Performance: Validation Study of Ability Scales for Classifying Human Tasks. Washington, D. C.: American Psychology Association, JSAS, 1973.

Williams, M. and Herbert Lissner. Biomechanics of Human Motion. Philadelphia, Penn.: N. B. Saunders Co., 1962.